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Chapter 8

THE FORMATION OF COMMON NORMS ON THE ASSUMPTION OF 'FUNDAMENTALLY' IMPERFECT INFORMATION

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Abstract The role of social norms is to process 'fundamentally' imperfect information. Information about future events, often needed in economic activity, is inevitably imperfect, since there's no way to check its correctness from our subjective viewpoint. The reason to be able to act well in spite of 'fundamentally' imperfect information is that we have social systems available to process and complement imperfect information. In this article, the problem of transferring information between agents is investigated with a multi-agent model. The model represents dual subjective interpretations of information by agents, information senders and receivers. Two types of norms emerge in the agents' system. One is the norm between senders and receivers, and the other among receivers. The former facilitates clear communication between senders and receivers. On the other hand, the latter intervenes to form the former norms. The receivers decide their action by referring to others' behaviour, so some clusters are formed. It is notable that the relationship between intervals of referring to others' behaviour by receivers and the average size of clusters is a power. This means that even if the agents seldom refer to others, there is a possibility of clusters emerging. Economic implications of our model and results are discussed.

Keywords: Multi-Agent Model, 'Fundamentally' Imperfect Information, Norm Formation

1. INTRODUCTION

This article deals with the role of social norms, when information is transferred between individuals. When a person engages in economic activity, he has to make use of several kinds of information to predict its result. In modern economics, the problem of collecting information is reduced to deciding individuals' payoff functions. We have regarded individuals and firms as being isolated from others and we have supposed that they are not influenced by the action of the others. Recently, the development of game theory shows that the others' action affect the isolated agent's decision making (Farrell and Saloner, 1986; Katz and Shapiro, 1985). New Institutional Economists correctly pointed out that social institutions are established as a result of the interaction of human beings (Aoki and Okuno, 1996; Aoki, 1997) [1]. Human action is decided by the interactions between the cognitive framework and information which we get. However, even in new institutional economics, information is assumed to be appropriately processed in advance and the cognitive framework of each agent is assumed to be fixed. Although this assumption is natural from the viewpoint of standard economics, most economists overlook the fact that information acquires meaning through the subjective interpretation of individuals. When we consider the role or function of social institutions, it is important to take into account the individual's interpretation of information because while social institutions emerge from the interaction of individuals, they affect formation of our cognitive framework. The institutions are, to quote Veblen (Veblen, 1919, Page: 239), "settled habits of thought common to the generality of men."

In considering this problem, we have to change the concept of information in economics. In economics, information has been divided into two classes, perfect and imperfect. When we can obtain perfect information, there is perfect competition and this means the efficient use of resources (Arrow, 1984b; Arrow, 1984a). On the other hand, when information is restricted for some reason, the competition is imperfect and the inefficient use of resource appears. The argument about this dichotomy of perfect-imperfect information has been supported not only among the people who assume perfect information or perfect rationality, but also among people who criticize it and assert that information is imperfect or rationality is bounded.

However, the useful information in real economic activities is 'fundamentally' imperfect information about the events which will happen in the future. It is impossible to give a definition of 'perfect' information in this case. There is, for example, a set of information A which informs us concerning the future event X. This set of information A tells us something about the future situation, but it does not include anything to justify its correctness. Thus, when considering its correctness, we have to obtain a set of additional information B. In this time, however, we need to check the correctness of B. So we have to acquire more additional information C. We cannot cut this infinite chain of additional information logically, and only after event X happens, can we confirm the correctness of each information. Thus, economically useful information is 'fundamentally' imperfect[2].

While most modern economists think that social loss is caused by imperfect information that is often related to the irrational actions of economic agents, in the real world, we basically cannot have the perfect information or rational actions. However if we accept the concept of 'fundamentally' imperfect information, the conception of processing information in economic society has also to be necessarily changed. We think that information is processed not only by individuals, but also partly by social institutions. To put it concretely, the social institutions influence the formation of the cognitive framework of individuals by limiting the number of options[3].

In this article, we suppose norms are strongly related to such systems. We can regard norms as one part of social systems which are formed by accumulating a lot of people's experiences. Although it is, of course, possible that some institutions such as traffic rules prescribe behaviour of people, the problem of such kind is not in question here and we concentrate the institutions or social norms as the spontaneous order which is suggested by Hayek (Hayek, 1960; Hayek, 1988), because the conception of such institution has directly relate to the cognition of individuals. Everyone can reduce the possibility of facing uncertainty in daily economic life as long as they behave consciously or unconsciously according to institutions or norms. This is one reason why people make a society. We usually consider the information obtained as dependent not only on personal experience but also on other's experiences which are accumulated in a society. In doing so, we can greatly reduce the cost that we have to pay when we judge the correctness of information, and the possibility of encountering uncertainty.

However it is true that this type of norms does not strongly regulate human actions. Recent studies in cognitive psychology show that this kind of norms, for example language, affect ability of thinking but its influence is not so strong (Weiskrantz, 1988; Pullum, 1991). Despite this fact, this type of norms is worth considering because there are a lot of norms of this kind, for example, customs, habits, language and tradition, and they play an important role in our society. Moreover, this argument could be applied more complicate problems in politics, economics and sociology like the relationship between a market and culture or communities.

In this article, we analyse problems which emerge in the process of forming communication frameworks between individuals. When two agents communicate with each other, they have to receive and understand signals from the other. To communicate successfully, they have to consistently interpret signals which they receive. It is clear that it is difficult for communication to be successful when a sender and a receiver interpret the information according to their subjective frameworks. In such situations, the feasibility of transferring correct information seems to be reduced.

However, considering the formation of an interpretation framework is not important in this article. Our main purpose is to consider the influence of the action that is often observed in our society, when agents cannot have rational grounds for their judgments. In our model, the assumption of rules of behaviour is not so complicated and each agent does not have a great ability. The agent in our model has two abilities; (1) to know the result of his behaviour and to compare it with his neighbours, (2) to imitate the action of others. However, we assume that each agent cannot directly observe others' cognitive framework. This model shows how the action referring to others affects the formation of norms of agents.

To consider this problem, we adopt the agent-based system because it is suitable for the study of subjectivity of agents. Recently emergence and evolution of social norms have been studied with multi agent systems (Castelfranchi et al., 1998; Conte and Castelfranchi, 1995; Saam and Harrer, 1999; Shoham and Tennenholtz, 1997; Walker and Wooldridge, 1995). However, little attention has been given to the problem of subjectivity of information in these studies. In our model, a dual two-dimensional layer is used to express interaction between groups processing information. Each agent has its own framework to interpret information and exhibits a kind of adaptive behaviour to revise it. Supposing that each agent revises his interpreting framework in such a way, each agent can behave well in the end. The feature of this model is that we do not assume that agents have an intelligent mechanism. For, our main purpose is not to consider what kind of intelligence an agent needs to form the norm but to study how agents who have limited ability obtain a consistent cognitive framework by gaining experience and using social institutions. In other words, the aim of this paper is to ask why people can behave coherently although they cannot obtain such a framework by themselves. So in our model, each agent cannot know his or her own cognitive framework. By the adaptation of each agent, however, a kind of norm as a cognitive framework is established in a system of senders and receivers. As an effect of the norm, agents come to act successfully even if their behaviour is initially random.

In the next section, we explain more precisely the setting-up of the model. In the third section, we show the simulation results. Economic implications of our results are considered in the fourth section. The final section is devoted to the conclusion.

2. MODEL

The features of this model are that it is agent-based model, has dual layers, and the structure is based on adaptive behaviour. This model illustrates interactions between two planes, one consists of information senders and the other its receivers. Both planes have 20×20 cells, so there are 400 agents on each plane. Each agent has 8 neighbours. The boundaries are periodic.

2.1 MODEL SETTINGS

Original Information and Interpretation. Information senders and receivers interact by processing information with their own interpretation filters at many time. At the beginning of each turn, the original information is created at random. This information is expressed in the form of 10 binaries.

We here adopt exclusive-OR, hereafter it is denoted by XOR, as the interpretation method[4]. The XOR operation gets two input bits and returns '0' for the same bits and '1' for the different bits. This is illustrated by Table 8.1.

Senders. Each sender interprets the original information through his own filter which consists of 10 binaries. This assumption shows that senders themselves cannot directly know the original information. He is employed by receiver agents as their information supplier and sends the information which he was processed to receivers who are his clients.

Input(Original Info.)	Input(Filter)	Output(Interpreted Info.)
0	0	0
0	1	1
1	0	1
1	1	0

Table 8.1 Interpretation by the bit operation of exclusive-OR

At the end of each turn, senders compare the number of clients with their 8 neighbours. If all neighbouring agents of a sender have more clients than the sender, he revises his filter. Otherwise when he is not the bottom sender, or when he is the least popular but another sender amongst his neighbours has the same popularity as him, he does not change his filter. The way to revise is that he copies a concatenate part of a filter of the most popular sender amongst his neighbours with a probability μ_S. The length to copy is L_C and the start position in the filter to copy is decided randomly. If the copied part reaches the end of the filter, the remainder is restarted from the beginning of the filter[5]. If more than one sender has obtained the largest number of clients, one of them are adopted randomly.

Receivers. Each receiver interprets the information sent from his information supplier through his own filter with XOR operation. The filter is a 10-bit string, too. Re-interpreted information is compared with the original information and how many figures they can obtain correctly is measured as his score.

A receivers whose neighbours get higher score than him changes his way of behaving in the following two ways:

1. Every time he is the lowest ranked agent, he randomly flips one bit in his filter with a probability μ_R.

2. When he stays at the bottom isolated for longer than r turns continuously, he changes his supplier to one who is employed by the best receiver amongst all his neighbours. If more than one receiver has the best score, one of them is selected randomly.

Otherwise, he changes nothing. The score each receiver gains is returned to zero at the end of each turn. The value of r is a control parameter which represents the frequency with which others behaviour is observed.

2.2 CHARACTERISTICS OF THE MODEL

Finding Filters with Each Other. As we can easily understand, receivers have to prepare the same filter as their suppliers, because both senders and receivers use XOR as their interpretative method. They, however, can not directly observe the filters of their suppliers and of neighbouring receivers. They should manage to find the filters of their suppliers by internally changing of filters based on comparison of their scores with their neighbours. However, suppliers' filters also continue to change. On the one hand, receivers have to find senders' filters in order to obtaining correct information. On the other hand, senders have to find a filter which is popular among receivers to acquire more clients.

The Local Irrational Behaviour. It is clear that senders' and receivers' action are not rational at a local level. In senders case, even if a sender completely copies the filter of the most popular one, he cannot increase his number of clients unless receivers choose him at least once and prepare a similar filter to his.

In the case of receivers, the internal filter change is a completely random process, without any memory and strategy. When a receiver changes his information supplier, he cannot gain a higher score without finding a suitable filter. It is rather irrational because he has to begin making an effort from the start. Therefore, their behaviour has no rationality at least in the short term and at local level.

Despite the lack of smartness, the whole system is sufficiently adaptable to reach a better outcome, as will be mentioned in the next section. The key to this game is to see how agents attain a better outcome in the long term from macro and micro viewpoints.

3. SIMULATION RESULTS

The model is run within the following parameters: the probability of changing senders' filters, μ_S, is 0.05; that of receivers', μ_R, is 0.05; the length to copy the senders' filter, L_C, is 3. The interval to revise suppliers by receivers, called the interval of revision and denoted by r, is a control parameter. The initial filters of senders and receivers are randomly set. The supplier of each sender initially is also randomly adopted.

3.1 CLUSTERING IN SUPPLIERS AND FILTER PATTERNS

Senders form clusters as shown in Fig.8.1. This figure depicts the transition of change of the suppliers adopted by receivers in the course of the simulation for $r = 1$. Receivers in a region painted the same brightness in the figure employ the same sender. From the initial random distribution, clusters grow in size and finally they become one or a few large groups around $t = 500000$. The cluster formation is caused by the revising action of receivers as they adopt the same sender as the top scored receiver in their neighbour.

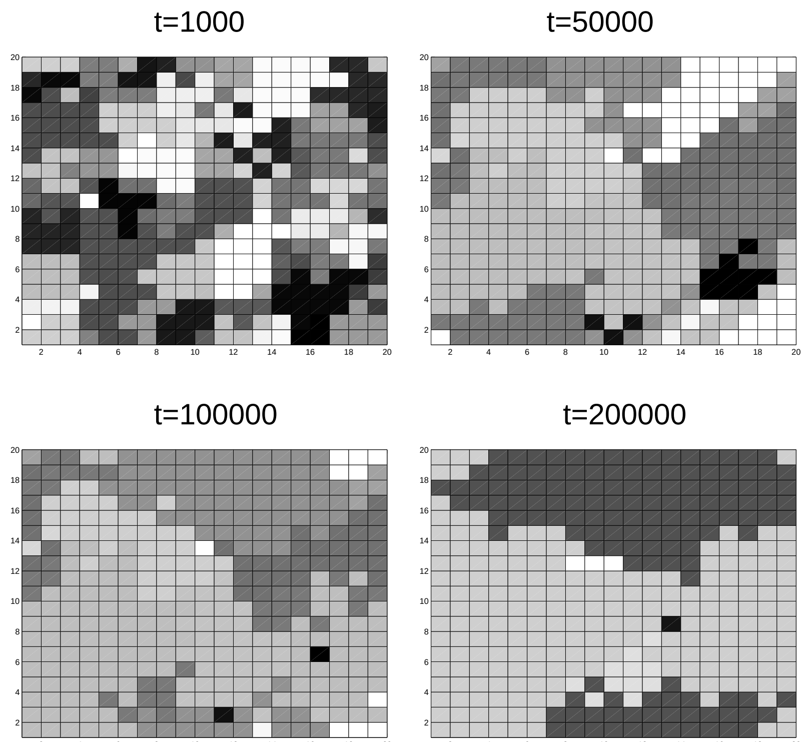

Figure 8.1 Transition of distribution of suppliers adopted by receivers at turn 1000, 50000, 100000, and 200000 for $r = 1$. The figures express the receivers plane and each cell displays the supplier of a receiver. An area with the same brightness denotes that receivers in the cells in the area employ the same sender. We can see clusters adopting a supplier spread out through the simulation.

In spite of the fact that receivers cannot directly observe the filter pattern of neighbouring agents, their filters gradually become uniform in a cluster discerned by suppliers through the internal alterations of filters as depicted in Fig.8.2. Eventually, the senders' filter patterns accord with their suppliers'.

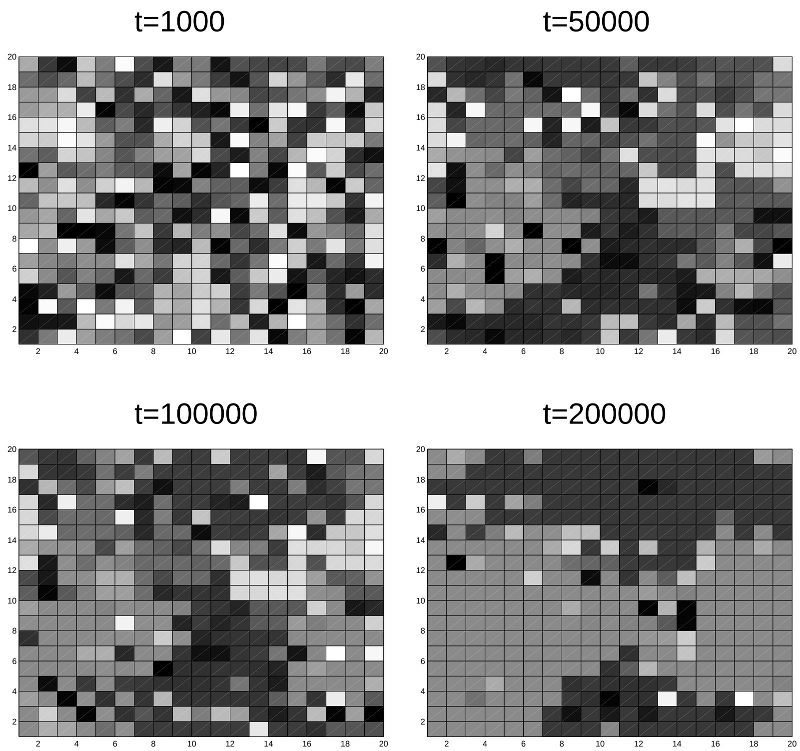

Figure 8.2 Transition of distribution of receivers' filter patterns at turn is 1000, 50000, 100000, and 200000 for $r = 1$. Each cell displays the filter pattern of a receiver. It can be seen that agents make clusters also in terms of filter patterns. However, growing clusters distinguished by filters runs behind clustering by suppliers.

Senders also make clusters by their filters as in Fig.8.3 which describes the distribution of filter of senders at $t = 200000$. The distribution reaches a stationary state much earlier than that of receivers. Few changes occur after the 5000th turn. Even if senders can copy a part of the filters from their neighbours, cluster size does not rise by as much as receivers'. Since, around this turn, only some senders have their clients and the others have the same number of clients, namely zero, they do not have the opportunity to change their filter patterns.

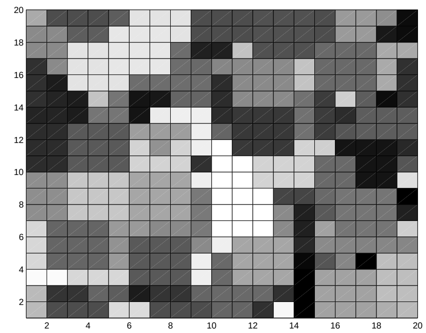

Figure 8.3 Distribution of senders' filter patterns at 200000th turn for $r = 1$. This figure shows the sender plane and each cell is the filter pattern of a sender. The cluster size is smaller than that of receivers'.

3.2 DYNAMICS OF POPULARITY OF SENDERS

Receivers switch the senders they are employing. In the process, we can observe that some senders who have not been popular enlarge their clientele. On the other hand, some senders who have achieved relatively more clients lose them gradually. The dynamics are exemplified in Fig.8.4. No agent who loses his clients once regains popularity again.

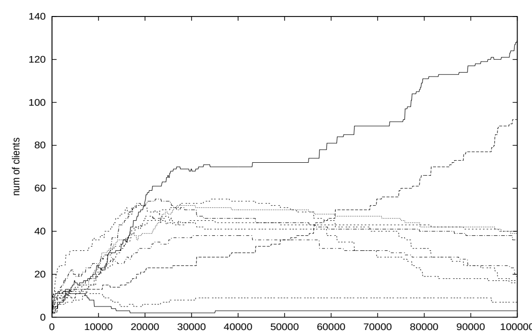

Figure 8.4 The time evolution of the number of clients for $r = 1$. The dynamics of the number of clients for the top 10 senders at $t = 100000$ are plotted.

3.3 DYNAMICS OF RECEIVERS' SCORE

All agents come to get the complete original information around the 500000th turns for all values of the interval of revision. That is, they obtain the same filter as their suppliers and get the maximum score. We can observe this final state however the parameters are set. However, the process of reaching the final state is not simple. A delay in the process of increasing the average score is often observed. The typical dynamics of the average score is shown in Fig.8.5. At first the score rises to about 7.5 points, namely agents recover 7.5 bits of original information on average, and remains constant or increases very slow for 5,000-10,000 turns. After a plateau the score goes up around 9 bits and then shows long term plateau or decline till $t = 150000$. Where after the score begins to grow once more and reaches full marks at around $t = 500000$.

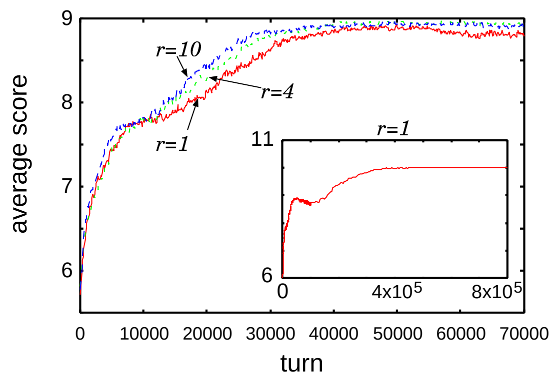

Figure 8.5 Transition of averaged score. Main plot compares the transitions for $r = 1, 4, 10$ up to $t = 70000$. A long term behaviour until $t = 800000$ for $r = 1$ is shown in the inset plot. We can distinguish a slowing down of increase from $t = 5000$ and a decline from $t = 60000$. In the short term plot the difference among r values is clearly seen between $t = 10000$ and 40000.

The final state and outline of receivers' score does not depend on the interval of revision. Until the lines of the graph begin to stagnate for the first time, until $t = 5000$, there is no big difference between each interval of revision ($r = 1, 4, 10$). However, the growth after the first period of stasis is different ($t = 10,000 \sim 40,000$). The score of the shorter interval of revision grows at a lower rate and is delayed until it reaches the second plateau, $t = 40000$. For much longer interval of revision ($r \gtrsim 30$), the tendency to slow down the increase is difficult to observe. There are no obvious differences in the dynamics of average scores between different intervals of the revision as well as the final state in the region of $r \gtrsim 30$.

Let us consider the reason why the slowing down effect is stronger when the interval of revision is short. When the interval is long, each receiver acts only because of the fact he has internally changed his own filter. The interactions with his neighbours giving an incentive to change his supplier seldom affects his action directly. Thus, we hardly observe the stagnancy or the decline of the increase of average score when agents revise their suppliers of information after a long interval. It comes to resemble a mere stochastic search.

On the other hand, when the interval of revision is short, each receiver's action is frequently affected by his neighbours because he often refers to action of others. As a result, standardization of information suppliers by the receivers takes place and the 'rock-in' effect becomes effective. After that, the incentive to change supplier is lost because receivers change their filter internally and gain high scores.

However, receivers at the boundaries of clusters cannot improve their score if they change their suppliers very often. Receivers at the boundaries are likely to adopt a different supplier from the previous one. The action of changing suppliers is not necessarily rational for receivers, at least in the short term, because they must abandon their effort to adapt to suppliers whom they have adopted when they change suppliers. This effect of the cluster boundary is stronger for the shorter interval of revision than the longer one.

3.4 POWER LOW DEPENDENCY OF NUMBER OF CLIENTS ON INTERVAL OF REVISIONS

We calculate the average number of clients of the senders having at least one client. Furthermore, the number from 200 simulations with the same parameters and different random initial values are averaged. The averaged value is denoted by $\langle c \rangle$. The result of this calculation is exhibited in Fig.8.6 with its variance indicated by error bars. In the short interval of revision, the average number of clients is heavily influenced by the interval of revision and its variance relatively wide. We cannot see a difference when the interval is very long.

We confirm that there is relationship between the interval of revision and the average number of clients. In $r = 1$ to 100, we compare the data plot with the function

$$\langle c \rangle = ar^{-b}$$

and they almost completely correspond at $a = 39.95, b = -0.3704$ (see the inset in Fig.8.6). This tendency can also be observed between the variance of the data and the interval of revision. This fact supports the cluster formation in our system and reveals that agents make clusters even when the interval of revision is extremely long.

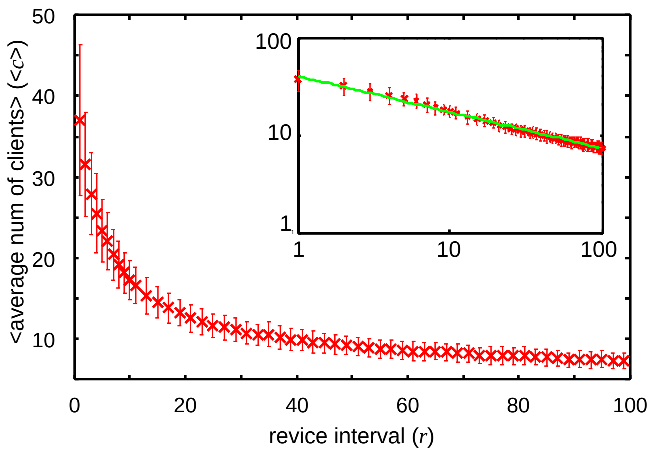

Figure 8.6 Average number of clients and its variance v.s. Interval of revision. The vertical bar at each point indicates the variance of the number of clients in 200 simulation results. In the inset plot, both axes are scaled logarithmically for the same data. The straight line is a function $\langle c \rangle = ar^b$, where $a = 39.95, b = -0.3704$. It is clearly shown by the plot that the relation between the average number of clients and the interval of revision obeys a power low.

3.5 PARAMETER DEPENDENCIES

The parameters related to filter change, μ_S, μ_R, and L_C, are selected to make the results clearly visible in the above report. None of them does not affect the final state and the power low dependency of $\langle c \rangle$ on r, substantially. The dynamics shown here are robust for almost all value of μ_S, and L_C, since the senders' filter copy occurs only at the initial stage of simulations.

If we make the value of μ_R large, the system reaches at the final state earlier. This acceleration is done by putting out the second plateau or decrease in the transition of receivers' average score, depicted at $t = 50000 \sim 150000$ in Fig. 8.5. It comes to the full marks at the second climb. Before the increase, however, the average score often show not the plateau but the decline.

4. SOCIAL IMPLICATIONS

Whenever information is transferred, some kind of cognitive framework is necessarily formed. We can say that information and cognitive frameworks cannot fundamentally be separated and that the meaning of information is decided in accordance with the relationship between information and the cognitive framework of a particular person. Moreover, we have to coherently interpret information in a social context. This means that cognitive framework of individuals has to acquire some not only internal coherency in each mind but also people to some extent external consistency with others. In other word, we should share an appropriate cognitive framework with others to act appropriately in our society. In this sense, the cognitive framework is the basis of social norms.

Our model expresses the inseparable link between information and the cognitive framework of agents. However, in our model, the result of an emerging appropriate cognitive framework is trivial because it is a logical consequence of the setting up of our model. Our main purpose is to observe the influence of referring to others' action when the agents do not have rational grounds for their actions and as a result, we have confirmed that receivers share the cognitive frameworks. We can define this as the formation of a second type of norm in our system. The agents sharing a framework interpret information in the same way and will behave coherently. The agents observe others more frequently, the larger groups of shared norms are formed. This result may explain the phenomenon of some kind of life style coming into fashion. A fashion is likely to occur in a society with people who are sensitive to others.

Sharing norms in this paper suggests a negative effect. In the result mentioned above the average score of receivers shows that regarding the observation of others' actions as important hinders the formation of a cognitive framework to interpret information correctly at the borders between groups of norms. Since we usually belong to multiplex norm groups simultaneously in modern society, we may receive different information even about one subject from many information suppliers.

Axelrod has presented the spatial array in which agents with various strategies such as tit-for-tat play the Iterated Prisoners' Dilemma game (Axelrod, 1984). In his model, a player's strategy is replaced by that of the player who has made the maximum gains among his neighbours after the Prisoners' Dilemma games. In a case where the spread of strategy is caused by invasions or transplants, there is no problem. However, in a case that it is caused by mimesis, the subjectivity of information should be again considered. Players can mimic only externally observable actions or strategy which is inferred from observable actions. The players hardly perceive real internal strategies of others[6]. We model the change of cognitive framework by updating filter patterns. Since a cognitive framework is not observable from outside, we assume that a receiver deduces the filter of others from their apparent behaviour. For senders, we assume the know-how to process information is observable to some extent. But since it is not perfect, only part of the filter pattern is mimicked and the pattern to mimic is randomly decided.

In this model, information is expressed with meaningless binary strings, but it is easy to give them some significance and this can be applied to more concrete problems, for example, speculation and information in a stock market. When we apply the present model to a stock market, it is important to understand the implication of the clusters that form. The result of this model shows that when the interval of revision is shorter, the period to escape inappropriate solution is possibly longer. As Keynes pointed out, there is the problem of the so-called 'beauty contest' under uncertainty (Keynes, 1973, Page: 156). We can arrive at the same conclusion as Keynes who argued that in the stock market where there is always uncertainty, speculators prefer a brand which selects rather than one which has unfulfilled potential as a result referring to action of others.

We can, indeed, offer a new viewpoint on the issue of network externality. It hardly needs to be said that in some kind of commodities which have network externality, excess inertia or excess momentum is caused by the action of referring to others' action (Farrell and Saloner, 1986; Katz and Shapiro, 1985). However, the present model suggests that in our real society with 'fundamentally' imperfect information the action of referring to others' behaviour causes such hindrance in the case of not only special goods but also ordinary goods and service. It is shown that the relationship between intervals of revising information suppliers and the size of clusters is a power. This result suggests that there is a possibility of forming norms even in a society with limited communication. In modern economics, it has been assumed that if a degree of isolation of agents occurs, then they rarely behave as a group. That is to say, we tend to deduce that it is difficult to form clusters when the interaction is unusual, because forming a group depends on the local interaction between agents. However, the decreasing tendency of the group size expressed by $< c >= ar^{-}b$, where r is the interval of observation on neighbourhood, suggests that in most situations, there is a possibility that a group in which every member adopts the same norms may emerge. We can use this result to explain, for example, the spread of social institutions or fashions between isolated societies, such as villages in the Middle Ages (Ginzburg, 1979) or in the Amazon. In villages such as these are isolated and only a few people travel between habitations. Despite of these situations, our result suggests that there is a possibility of spreading the same kind of custom.

Moreover, the results in which there is the possibility of organizing clusters and of delaying the formation of appropriate norms by clustering present a problem in that such a model which presumes isolated agents like the perfect competition model cannot approximate to our real world.

Reflection on some of these points makes clear that when we consider social phenomena, we should not assume fixed and isolated men, but men who continuously change their cognitive framework under the influence of others. Our model shows that even weak interaction with others makes a huge difference to the process of the formation of individual cognitive frameworks.

5. CONCLUSION

In this paper, we consider the conception of information that acquires its meaning through subjective interpretations. In ordinary economics, we always regard information as that which is already transformed into an appropriate form. On the other hand, we consider the problem of 'fundamentally' imperfect information on the premise that frameworks for interpretations emerge from interaction between senders and receivers of information. Our model shows that establishing norms facilitates the transfer of information, but it is sometimes disturbed by a different type of norm organized through interaction between receivers. This result is considered as an expression of the problem of 'beauty contest' pointed out by Keynes. It is revealed that the size of group sharing a norm depends on with which the action of others is observed. This fact implies norm formation occurs in the majority of society even when communication between communities is rare.

Keynes also pointed out that the 'state of confidence' about what other people thinks is important when we have long-term expectation (Keynes, 1973, Page: 148). In our model, instead of checking the correctness of the information itself, each agent acts depending on the relationship to a certain information supplier. This relationship is formed on the basis of the previous interaction between senders and receivers. In this sense, we can say that reliability of information is represented by a norm which develops between the sender and the receiver.

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Notes

1. In economics, people who regard the institutions and the social norms as important are, broadly speaking, divided into two groups. The first group adopts a conception of social and cultural evolution. They think that our society consists of not only instinctive actions and rational behaviour but also habitual actions of agents. Moreover, in their argument, the feedback loop between society and individuals is also important. Friedrich Hayek and Thorstein Veblen fall into this category. The second one is dependent on the theory of transaction cost which is proposed by Coase (Coase, 1937). For example, Masahiko Aoki studies the difference between a typical American and Japanese companies and draws conclusion that both company systems have the path-dependent rationality and consist of context-dependent action of members in each system (Aoki, 1997). The position of this paper is relatively close to the former.

2. The conception of information is deeply related to the assumption about human agents in economics. Shackle is one of the economists who pointed out the incoherence of this conception in economics (Shackle, 1972). The argument in this article largely depends on his radical subjectivism.

3. In economics, probability has traditionally been used in dealing with uncertainty caused by shortage of information. However, Knight pointed out, the 'true' risk which we face in our economic society is uncertainty in which probability distribution cannot be estimated (Knight, 1933). In accordance with his argument, in this article, we think that the agent needs a too strong ability to know the probability of future events.

4. This interpretation method does not have any special meaning. We adopt it because of its convenience.

5. That is, filters are treated as having a circular structure in the copy process.

6. In the model of Nowak and May (Nowak and May, 1992), players adopts much simpler strategy. They always cooperate or always defect. In this case, the externally observable actions seem to coincide with the internal strategies. This coincident can, however, also be recognized only by external observers. Players cannot know whether strategy of others is always genuinely cooperative or whether they are pretending to cooperate as a result of some more complex strategy.

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