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A THEORY FOR COMPLEX SYSTEM'S SOCIAL CHANGE: AN APPLICATION OF A GENERAL 'CRITICALITY' MODEL

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ABSTRACT

Within the developed nations deterioration in the basis of society, as dramatically demonstrated by the Lehman collapse, has reached extreme levels, and currently the formation of pro-change agents is approaching a decisive stage. Here, we will construct a complex systems 'criticality' model, apply it to social change, and examine its reliability and validity. The model derived a power law distribution of the output of social change. The validity of the model was verified by examining vote shares of parties in Japan. Based on the results of this examination, we propose a new quantitative strategy "information entropy enhancement" for social change.

KEY WORDS

complex systems social change, criticality, power-law distribution, information entropy enhancement strategy, vote share

CLASSIFICATION

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INTRODUCTION

Complex societies, such as the developed capitalist country of Japan, are networks of complex systems that evolve around the focal point of struggle between pro-change and pro-establishment powers. The pro-change forces are in turn composed of networks of complex systems having diverse connections (information, needs, movements, cooperation/collaboration etc.) between various individuals and groups, in order to break free of existing systems and effect a shift to a new system. Social change manifests in the 'critical state' of mutual antagonism and conflict between the pro-change and pro-establishment powers, while the dimensions of the change (quantitative and qualitative) are defined by the network pattern of the pro-change power. Simultaneously, the heretofore dominant pro-establishment power is relegated to a secondary role. In this article, we will generalize the quantitative theory of adaptive animal behavior [1-3] into a 'criticality' model of complex systems (Appendix), apply it to the quantitative aspects of social change, construct a model for complex systems social change, and examine the model's effectiveness.

A COMPLEX SYSTEMS SOCIAL CHANGE MODEL

The criticality model of complex systems can be applied to the dynamics of complex systems social change. Here, the pro-change power of the complex system society is considered to be the confrontation power, constructed from complex system networks of diverse connections between various individuals and groups for the purpose of breaking free of the existing systems of the complex system society and effecting a shift to a new system. We will define the number of diverse and active individuals and organizations that structure the pro-change power's network and are related to the output R as N. Following the criticality model, the number of network patterns, for example, an information exchange quantity (information sorts × frequency) is hypothesized as $I(\alpha N) \sim \exp(\alpha N)$ (see expression (1) in Appendix[1]).

It does not touch upon the details of mutual interactions between the various elements of the two conflicting powers. Hereafter, figures in parentheses indicate equations in Appendix. The existence probability of the number of network patterns of the pro-change power is given by $P(\alpha N)$ (2), while the existence (resistance) probability of the pro-establishment power acting upon the pro-change network is given by $Q(\beta N)$ (3). Assuming the social change output R is inversely proportional to the resistance probability $Q(\beta N)$ (4), we can use it to obtain the probability density function $\phi(R)$ (6) through variable transformation by R of the existence probability of the pro-change power, $P(\alpha N)$. Approximating the information entropy of the network of a social pro-change power N using H_M (9) leads to α_M (12), which incorporates the information effect in α. The criticality model of complex systems leads logically to the power law $\Phi(R) \sim R^{-D_M}$ ($D_M = \alpha_M/\beta$) for the social change output R. It should be noted that the size (strength) of the pro-change power defined by α_M and N_C (largest of N) does not directly correspond with the individual change outputs of R . Even if the pro-change power is constant, the change output R will be unstable and fluctuate greatly, following a power law distribution. The parameter of existence probability for the pro-change power is α_M; it is opposed to the pro-establishment power's resistance probability parameter β in contributions to the power exponent D_M. Consequently, D_M reflects relatively each agonistic probability, and therefore, real power relationship of both powers. Thus, it is difficult to grasp the agonistic structure directly from the output R, which expresses complex factors, but it can be captured via the power exponent D_M.

In order to increase the probability of true social change, the agonistic structure expressed by the power exponent must be greatly altered. To do this, the power exponent D_M should be decreased so that the change output should dramatically increase. In other words, $\alpha_M \sim \alpha_0 \exp(\Delta H)$ must be small (decrease ΔH), while β must be large, and the output R should be greatly increased. In particular, ΔH is very effective as it contributes exponentially to D_M. Given $\Delta H = H_0 - H_M$ (10), an effective strategy for social change should be increasing information entropy H_M in the pro-change power's network patterns (9) and reducing ΔH (i.e. amount of memory; quantitative theory of adaptive animal behavior [1-3]). Put another way, this model suggests that activities for complex systems social change should focus on informational and ideological confrontations via peaceful means, rather than forceful struggle. In order to test the validity of this model, the question of what to use to ascertain the multiple possible social change outputs is extremely important. Within developed nations, the foundation of society is a representative democracy composed of a party government. By way of addressing one social (change) output, we selected the share of votes received by political parties; their rates of change were then aggregated and analyzed over a number of years. The rate of change in the vote share is the absolute difference in vote share between one election and the next at fixed intervals. In terms of the model, by examining not the size of the rate of change, but rather the distribution's exponents, the agonistic structure (real power relationship) can be ascertained. In this paper we focus on the national elections held in Japan after World War II. In Japan many political parties were repeatedly launched, merged and divided during a period of seventy years after the war and at present eleven parties exist with seats in the Diet of Japan which consists of Upper and Lower Houses. Among the parties only the Japanese Communist Party, which is the third largest opposition party, and the Liberal Democratic Party, which is now in power, have been maintaining the unity over half a century. The other parties including the present largest opposition party, the Democratic party of Japan, have been founded recently. Hence, one understands that it is appropriate to choose the above two long-lived parties in the analysis of the agonistic structure in Japan. Specifically, we used national (1947-1980) and proportional-representative (1980-2010) Upper House elections, which are held regularly every three years and in which all of Japan is treated as a single constituency. First we will examine the Japanese Communist Party (JCP), which has long operated under the same name and has the largest sample size, and then the Liberal Democratic Party of Japan (LDP). Finally, we will look at the relationships between them.

RESULTS

JCP VOTE SHARE

Figure 1 shows the trend of the JCP's vote share in Upper House elections from 1947 to 2010. Twenty-two elections have been held during this time. The vote share changes dramatically, reflecting the complex political, economic, and cultural conditions of the times. At its peak in 1998, the JCP "surged" when the Hashimoto government suffered a major defeat after raising the consumption tax to 5 %, causing economic deterioration. As a dynamic output of social change, analysis is performed with respect to the rate of change R of the vote share[2].

Figure 2 shows a double logarithmic plot with the rate of change R on the horizontal axis, and the normalized number of elections with a rate of change greater than R on the vertical axis. Surprisingly, excluding five points of data in which the rate of change is small, the points fall along a single line and clearly exhibit a specific power-law distribution with an exponent of 1,27. As there seems to be nothing special about the times when the excluded five data points occurred, they can be regarded as noise from the view point of social change (since we are focusing on large R values). This result shows that there is a clear law governing fluctuations in vote share determined by complex, diverse factors in each era; in the case of the JCP's vote share, there exists a specific social change equation (power law distribution with the exponent

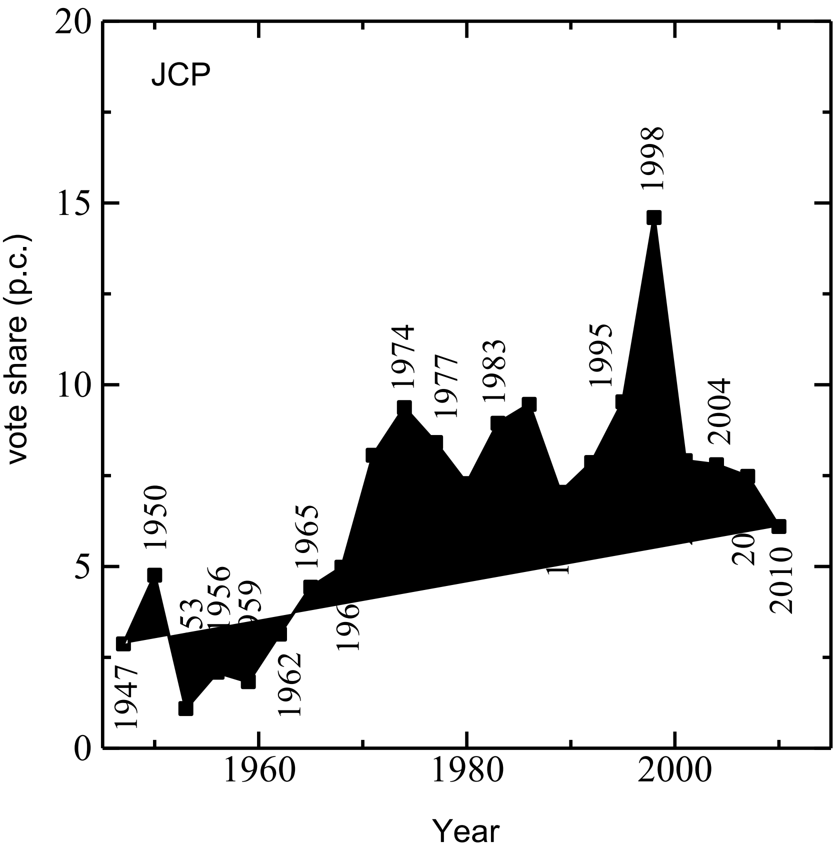

Figure 1. The trend of the JCP's vote share in Upper House elections from 1947 to 2010.

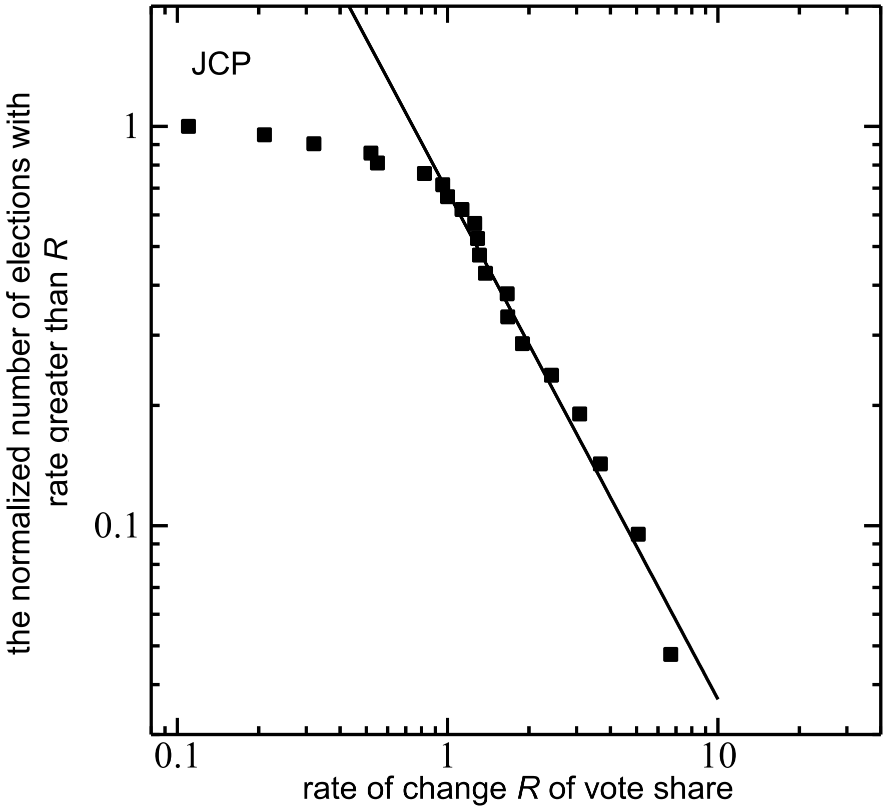

Figure 2. A double logarithmic plot with the rate of change *R* of vote share on the horizontal axis, and the normalized number of elections with a rate of change greater than *R* on the vertical axis. The power exponent D_M obtained in terms of the least squares method is 1,27.

1,27). Large fluctuations (e.g. 1998) conform to this equation and are not anomalous surges. That is to say, the election results, including the surges, have not changed the real power relationship as expressed by the power exponent 1,27.

LDP VOTE SHARE

Since its formation in 1955 through a conservative alliance, the LDP has lost twice to opposition parties, falling out of power for brief periods. Otherwise, it has occupied a central position as a consistently pro-establishment power. Figure 3 shows the trend of the LDP's vote share in 19 elections from 1956, the year after its formation, to 2010. Figure 4 shows a double logarithmic plot with the rate of change *R* on the horizontal axis, and the number of elections with a rate of change greater than *R* on the vertical axis. The majority of data points, 10 of 18, diverge from a straight line. Here, the power exponent is 2,27. Next, a single logarithmic plot of the same data is shown in Figure 5. All data falls along a straight line, and displays exponential distribution. This is in contrast with the JCP's power-law distribution.

RELATIONSHIP OF PARTIES' VOTE SHARE

Figure 6 plots the vote share of the JCP (horizontal axis) and LDP (vertical axis), showing the correlation between the two. It indicates a clear negative correlation. When the JCP vote share rises, the LDP share falls; the reverse is also true. The isolated point to the bottom-right represents data from the 1998 Hashimoto cabinet Upper House election, but aside from this point, the correlation coefficient does not fluctuate. This supports the validity of the assumption of the complex systems social change model corresponding to Eq. (4) in Appendix.

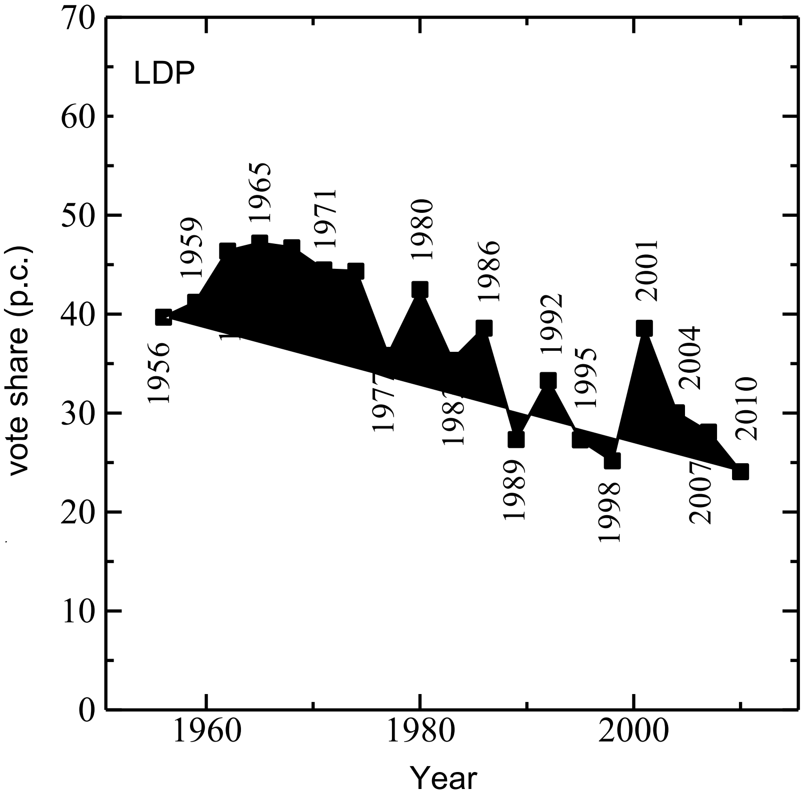

Figure 3. The trend of the LDP's vote share in 19 elections from 1956, the year after its formation, to 2010.

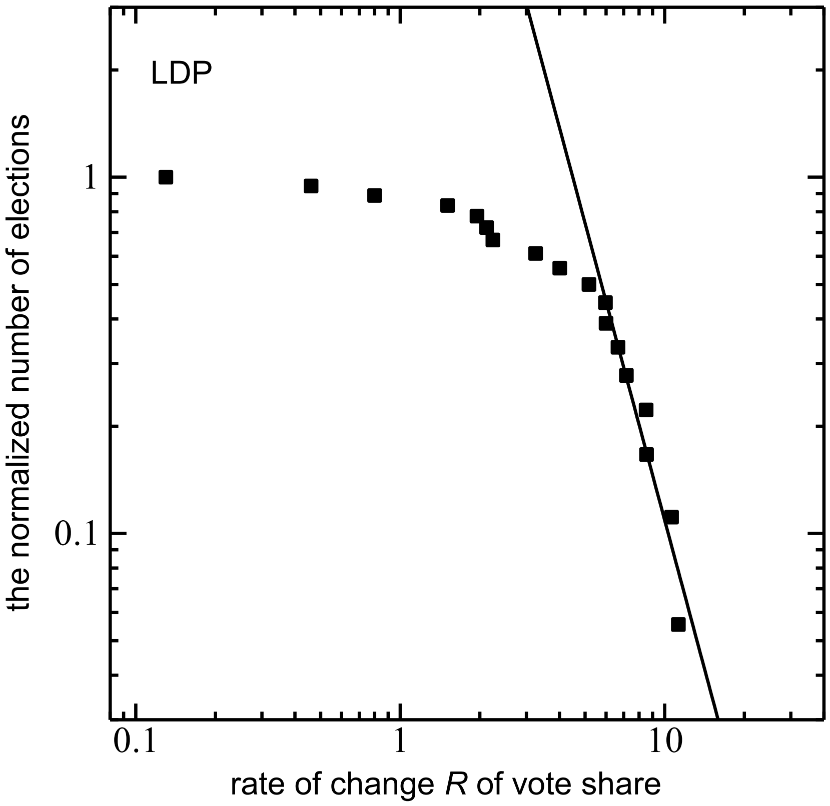

Figure 4. A double logarithmic plot with the rate of change R on the horizontal axis, and the number of elections with a margin of change greater than R on the vertical axis. The power exponent in terms of the least squares method is 2,27.

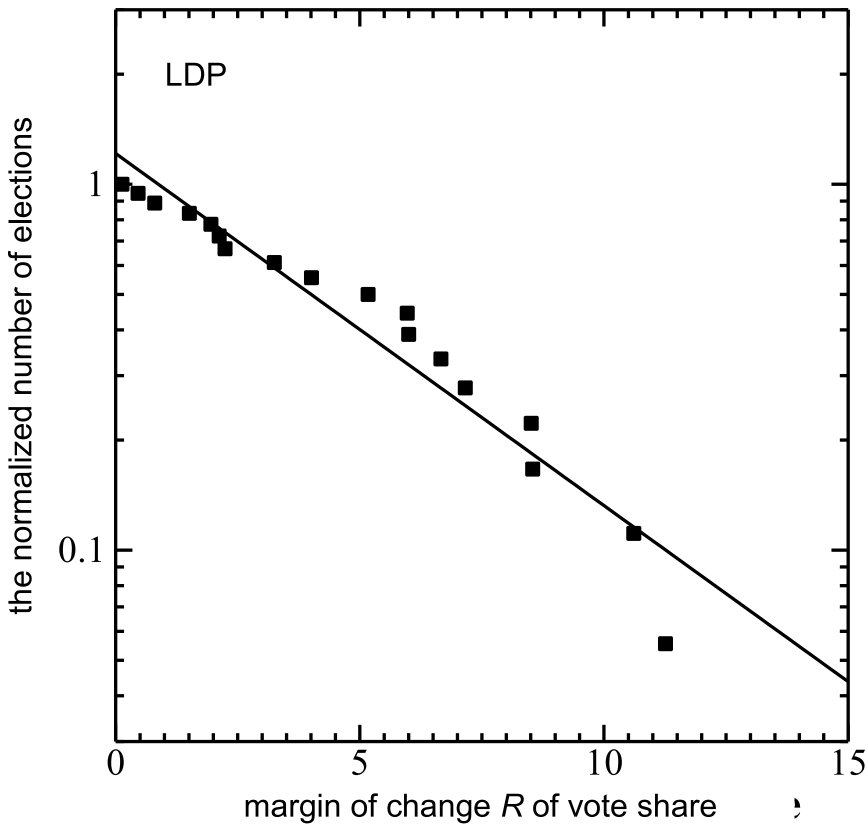

Figure 5. A single logarithmic plot of the same data as shown in Figure 4.

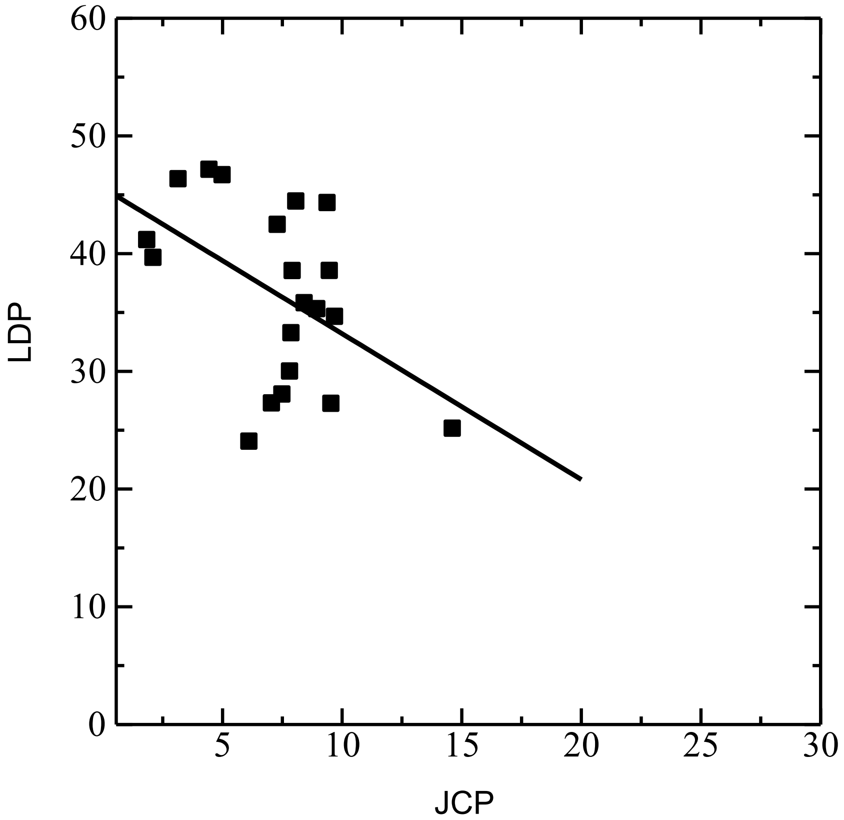

Figure 6. Plots of the vote share of the JCP (horizontal axis) and LDP (vertical axis). The coefficient of the correlation value is –0,48.

DISCUSSION

The JCP displays a definite power law and large changes in its vote share; within the model, it exhibits the characteristics of a pro-change power, which corresponds with its actual role. In contrast to the JCP, the LDP, which is regarded as the establishment party, exhibits an exponential distribution, and has a relatively stable rate of change with minor fluctuations. Viewed theoretically from the establishment side, when β is small, and the pro-change power's resistance probability $Q(\beta N)$ is small, this leads to the stable continuation of the exponential distribution (8). However, as indicated by the fallout from the Lehman collapse and the severe deflationary economic downturn in Japan, the buildup of discrepancies in the basis of Japanese society is reaching an extreme level. In order to break free from this stagnant era and open up future prospects, new strategy for social change is needed. Currently, the country is approaching a dramatic transition from the state of social change that has existed up until now (exponent $D_M = 1{,}27$) to a state of real criticality, the most probable for social change ($D_M = 1$). The model suggests that a decrease of the power exponent D_M (1,27) changes the agonistic structure greatly, leading to an increase in the change output R.

In order to decrease the power exponent $D_M = \alpha_M/\beta$ (slope), $\alpha_M \sim \alpha_0 \exp(\Delta H)$, thus a decrease in $\Delta H = H_0 - H_M$ will be effective. Consequently, increasing the information entropy H_M (9) of the pro-change power's network pattern should be effective for real social change. In other words, the model suggests an "information entropy enhancement" strategy. This raises the question of what it means to increase information entropy in the pro-change power's network pattern. First it means the expansion of the uncertainty and variety of information. It denies the concentration of specialized information, and expands a united front network composed of diverse singular issues (single points) – i.e. letting "a hundred schools of thought contend".

Moreover, in the quantitative theory of adaptive animal behavior, ΔH is the amount of memory, so reducing it should facilitate new information creation, sharing and dissemination, and departure from experientialism, the revelation of hidden social realities, etc. Stirrings such as the Arab Spring, Occupy Wall Street, and protests at the Prime Minister's residence (of Japan) are real examples of a new social change movement abroad and in Japan. Therefore, the central issues for social change movements are the informational and ideological struggle and the construction of a diverse social change network.

On the other hand, approval ratings for governments showed exponential distributions [4]. The results may indicate from our model that the approval groups examined were not in the ‘critical state’ of mutual antagonism and conflict between approval and disapproval groups.

The above is a quantitative discussion of social change based on models. It does not address the quality (contents) of change, such as what will change or what kind of society will be created. The united front strategy based on democratic reform theory [5] essentially and qualitatively defines the object of change above all else. The quantitative “information entropy enhancement” strategy proposed in this research is not inconsistent with the united front strategy; the two strategies can compatibly supplement one another. A deep analysis of the relationship between the two will be necessary in the future.

POSTSCRIPT

During the Upper House election on July 21, 2013, the JCP’s vote share surged from 6,1 % for the previous election to 9,7 %. This can be seen as the result of an, albeit unintentional, information entropy enhancement strategy of a diverse united front of singular issues (consumption tax, constitutional reform, nuclear power, the Great East Japan Earthquake, Trans-Pacific Partnership, American military bases, social security, etc.). However, upon analysis via the model for complex systems social change proposed by this research, there was almost no change in the power exponent, so this was not enough to alter the real power relationship of the agonistic structure. This also indicated that the JCP’s medium range vote share goal of 20 % should achieve a significant change in the power relationship.

CONCLUSIONS

We constructed a complex systems ‘criticality’ model, applied it to social change, and examined its reliability and validity. Social change manifests in the ‘critical state’ of mutual antagonism and conflict between the pro-change and pro-establishment powers. The model derived a power law distribution of the output of social change, the characteristics of a pro-change power, while a pro-establishment power displayed an exponential distribution. The power exponent reflects the agonistic structure (real power relationship) of both powers. The validity of the model was verified by examining vote shares of parties in Japan. Based on the examination, we propose a new quantitative strategy “information entropy enhancement” for effective change of the exponent, and therefore, for social change.

REMARKS

[1]This hypothesis is analogous to the Boltzmann distribution, but it is also a solution of $\mathrm{d}I(N)/\mathrm{d}N = \alpha I(N)$ which is often used in various growth phenomena. Recently, it was shown that the model holds when power law distribution N^{α} is hypothesized. Because $N^{\alpha} = \exp(\alpha \ln N) = \exp(\alpha M)$ when $\ln N = M$, all procedures in the model are the same for M. This result suggests that the assumption of exponential function in equation (1) is not essential; a model can potentially be realized if there exists an increasing function.

[2]The rate of change R in the vote share is the absolute difference in vote share between one election and the next.

APPENDIX: COMPLEX SYSTEMS 'CRITICALITY' MODEL

GENERAL THEORY OF THE 'CRITICALITY' MODEL IN COMPLEX SYSTEMS

Criticality refers to "a state in which two powers both act towards creating a different state, and in so doing both achieve a state of precise balance" (Butsurigaku Jiten in Japanese). However, research [6] indicates that in complex systems multiple metastable self-organized critical states are formed. The word 'criticality' is used here in quotes to distinguish it from the precisely balanced criticality of simple systems physics. Hereafter the term will be used as-is, without quotes, to indicate criticality in complex systems, unless otherwise noted.

The criticality model of complex systems is predicated on a fundamental idea of complex systems, namely that "complex system dynamics and its output (quantitative, qualitative) are defined by a network pattern of diverse mutual interactions (physical, informational, social) working among N active elements that are related to output, within the elements that comprise the system". This view of complex system dynamics has come to be shared in recent years. However, this model is limited to the quantitative aspects of the system, and is based on the assumption that the output is defined by the existence probability $P(N)$ of the number of network patterns $I(N)$. In cases where a positive tendency and opposing anti-tendency are observed on that network, the existence probability $P(N)$of the number of network patterns $I(N)$expressing the positive tendency and the existence probability $Q(N)$ that its anti-tendency can take, describe the two conflicting tendencies in terms of probability theory. These do not touch upon the details of mutual interactions between elements. As shown in the next section, the output R of a critical state in a system with two opposing, mutually-antagonistic tendencies, logically leads to a power-law distribution. As far as we know, there are no previous examples of power-law derivation in complex systems based on the above assumption, and thus this assumption's validity must be tested by applying it to various complex phenomena. When doing so, it must be acknowledged that an output system will form in which qualitatively different outputs will exist even for a single complex system and each of these could in turn manifest multiple quantitative outputs. For example, in animal behavior, these could be the duration of the behavior [1-3], its intensity, scale, etc.; in earthquakes, the earthquake's energy or magnitude [7], duration, fault surface, etc.; in a conflict, the number of casualties [8], length of the conflict, etc.; and in social change, these could be the percentage of votes taken by the pro-change power in the present paper, participants in protests, etc. The question of what to capture as the output is extremely important when examining the model, but only the quantitative aspects of the output can be analyzed/examined.

DERIVATION OF THE CRITICALITY MODEL OF COMPLEX SYSTEMS

Suppose N is the number of active constituent elements that determine a complex system's dynamics. Assume a number of network patterns $I(N)$ of mutual interactions between those elements in the following equation (and see remark 1)

$$I(N) \propto \mathrm{e}^{\alpha N}\,. \tag{1}$$

α is a parameter that expresses rate of growth with respect to N of the number of patterns $I(N)$. The existence probability $P(\alpha N)$ of the number of patterns $I(N)$ is expressed as,

$$P(\alpha N) = \frac{\mathrm{e}^{-\alpha N}}{\sum_{N=0}^{N_C} \mathrm{e}^{-\alpha N}}\,, \tag{2}$$

and so the largest number of active elements is N_C. In the system's critical state, the existence probability $Q(\beta N)$ of the number of patterns of anti-tendencies, acting in opposition and antagonistically to this network of positive tendencies, is expressed as a similar exponential function, with the parameter β generally differing from α

$$Q(\beta N) = \frac{\mathrm{e}^{-\beta N}}{\sum_{N=0}^{N_C} \mathrm{e}^{-\beta N}} \tag{3}$$

$P(\alpha N)$ and $Q(\beta N)$ are common simple function types that have interesting and somewhat complex characteristics. Both are monotonically decreasing functions of N, but if one examines the dependency on α or β, when α is sufficiently small, $P(\alpha N)$ is also small ($\sim(N_C + 1)^{-1}$), but largely depends on N. That is, when $0 < N < N_C/2$, a single extreme value exists for a given α, and when $N_C/2 < N$, it monotonically decreases with respect to α (unpublished).

Next, these two probabilities express two opposing tendencies, and define the output system R that is produced from the conflicting critical state; this results from the following. Initially, as the output R will probably decrease as anti-tendencies strengthen, it is assumed to be inversely proportionate to the probability $Q(\beta N)$, so R is defined by βN.

$$\frac{1}{R} = \frac{1}{R_0} Q(\beta N) = \frac{1}{R_0} \frac{\mathrm{e}^{-\beta N}}{\sum_{N=0}^{N_c} \mathrm{e}^{-\beta N}} \tag{4}$$

Moreover, if R is sufficiently large and integral (and continuous) representation is employed, $\phi(R)$ is the probability density function of R. Through variable transformation by R of the existence probability $P(\alpha N)\mathrm{d}N$, the probability $\phi(R)dR$, which expresses the structure of the output system R, is acquired (probability conservation). That is, given $\phi(R)\mathrm{dR} = P(\alpha N(R))(\mathrm{d}N/\mathrm{d}R)\mathrm{d}R$,

$$\frac{\mathrm{d}N}{\mathrm{d}R} \propto \frac{1}{\beta} \mathrm{e}^{-\beta N}, \tag{5}$$

which follows from Eq. (4), then

$$\phi(R) = P(\alpha N) \frac{\mathrm{d}N}{\mathrm{d}R} \propto (\mathrm{e}^{-\beta N})^{\alpha/\beta} (1/\beta) \mathrm{e}^{-\beta N} \propto (R/R_0)^{(-\alpha/\beta - 1)} \tag{6}$$

Integrating this (cumulative distribution)

$$\Phi(R) = \int_R^{\infty} \phi(R)\mathrm{d}R \propto (R/R_0)^{-\alpha/\beta} \tag{7}$$

yields a power-law distribution expressing the structure of the complex output system R. With regards to α and β, opposite tendencies are expressed by the numerator and denominator in $D_M = \alpha/\beta$. However, if β is sufficiently small, this will become an approximately exponential distribution:

$$\Phi(R) \propto \exp(-\alpha R / R_0 \beta) \tag{8}$$

The complex system is simultaneously a complex material system and a complex informational system. In order to quantitatively handle the complex system, we will introduce the complex system network's information entropy (mean information amount) H_M to the model. Shannon's definition of information entropy H_M is expressed as a discrete equation, but it can be approximately expressed as the following integral representation.

$$\int_0^{N_C} \mathrm{d}N \left[-\log P(\alpha_M N)\right] P(\alpha_M N) \equiv H_M \tag{9}$$

Here, α_M and $P(\alpha_M N)$ are the parameter and existence probability, incorporating the information effect. If the change in information entropy of the complex system network ΔH is

$$\Delta H = H_O - H_M \tag{10}$$

(H_0 is the maximum value of H_M at the time α_M changes), then when N_C is large [3]:

$$H_S \approx 1 - \log \alpha_S \, (s = 0 \text{ or } M). \tag{11}$$

H_S is expressed by α_S, therefore:

$$\alpha_M = \alpha_0 \, e^{\Delta H}. \tag{12}$$

Consequently

$$D_M = \frac{\alpha_M}{\beta} \tag{13}$$

Thus, D_M is shown to change depending on ΔH. However, it may be necessary to incorporate the information effect in the probability $Q(\beta N)$ for specific complex phenomena.

SIGNIFICANCE OF MODEL

This model illustrates one general expression of the laws of transformation and criticality, which comprise the foundation of the developmental/evolutionary processes of complex systems. Moreover, it points to the importance of the meaning of and changes in the power exponent D_M in complex system dynamics that express the power-law, suggesting that in these changes, the contribution of ΔH is (exponentially) large. In fact, in the adaptive animal behavior model [1-3], which is the basis for this model, it has been clearly demonstrated, through five independent experiments, that changes of the power exponent D_M depend on amount of memory (ΔH) and gustatory stimulus (β).

Up until now, it seems that many complex systems models are used to provide feasible, a posteriori explanations, or to tout new and different interpretations [9]. Perhaps we are merely ignorant of their existence, but there seem to be almost no widely effective and potentially predictive theories (models). In addition, there have been almost no examples of research that directly explore changes in the exponents of power law within complex systems science. Rather, the research attempts to evaluate the universality of power exponents beyond differences of object. In elucidating the significance of power exponent dynamics within the same object, this model may clarify system structural dynamics, which are at the root of output fluctuations in complex systems, and suggests the potential of structural “change” and “control”.

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