

# An Agent-Based Study on the Relationship Between Tiao-kuai Structure and Fragmentation Phenomenon of Crisis Governance

Yun-Feng Wang<sup>(✉)</sup>

School of Economics and Management, Tongji University, Shanghai, China  
tjuwyf@tongji.edu.cn

**Abstract.** The relationship between fragmentation phenomenon and Tiao-kuai structure is a basic problem of Chinese crisis governance. An agent-based model is developed which has two actors, namely local government and internal bureaucracy agency. It sets capability utilization mode according to the relative bargaining power in urgent environment. After events randomly fall into their respective responsibility field, actor deals with events within ability field. Then the completion rate of utility filed events is calculated to evaluate the fragmentation degree. With exogenous capability allocation and utilization mode, Monte Carlo simulation experiments show that: (1) the fragmentation could be generated by the simplest Tiao-kuai structure; (2) the fragmentation seems inevitable in most cases; (3) local government should pay more attention on capacity allocation instead of utilization mode, but internal agency should keep eyes on both of them; (4) The best choice is equal distribution of capability no matter under which kind of utilization mode.

**Keywords:** Fragmentation · Tiao-kuai structure · Crisis governance · Agent-based computational organization

## 1 Introduction

Fragmentation of crisis governance has become a serious problem in China for many years. A huge amount of public sectors' capacity, such as resources, information, efforts, etc., has not appeared at the right time, with a right amount or in the right place. Given the size and urgency of the fragmentation issue, there have been considerable speculations about its causes. Influencing factors include government's power and function setting, operating methods, the way of stimulating and restricting government acts and so on [1, 2]. However, the organizational causations, especially Tiao-kuai structure, are very likely to be the underlying cause of this phenomenon [3].

The Chinese government system is a five-level hierarchy of dyadic nested structure. Two radically different structural approaches was used by national government: (1) the decentralization of economic and political decision making to local governments; (2) the partial centralization of a number of key bureaucracies in order to regulate and discipline local government agents. This governance structure is not a temporary

measure. And then the local government which consists of agencies of bureaucracy has to face the fundamental structural problems. Typically individual offices within these bureaucracies are no longer under the supervision of local governments (Kuai); rather, they are directly controlled by their functional administrative superiors (Tiao) [4].

Under such a structure design, the local governments' behaviors, to a large extent, are the equilibrium of a multi-player game of the government system. From top to bottom, the local governments' degree of freedom is shrinking and is imposed increasing rules by the inter-organizational network. The allocation and utilization method of capability could be regarded as an exogenous variable of local government.

Unfortunately, in the existing literature, organizational structure factor is often blended with other factors, which impairs the credibility of conclusions. For example, the role that Tiao-kuai structure plays in the creation of fragmentation is still not clear. And it is not sure whether the best game equilibrium that minimizes the fragmentation exists.

Therefore, this study attempts to address the above shortcomings and further explore the issue by experimentally investigating the following basic questions:

- (1) Does the fragmentation phenomenon of crisis governance really come from the Tiao-kuai structure? In other words, can fragmentation phenomenon be produced by a system which only has the simplest Tiao-kuai structure?
- (2) Are there any combinations of capability allocation and the rules of capability utilization that would satisfy both the local government and internal agency? That indicates improving or even eliminating fragmentation on both sides simultaneously.

## 2 Model

The conventional Tiao-kuai structure can be modeled as follows. Event set  $\Theta = \{\Phi_1, \Phi_2\}$  should be dealt by actor set  $E = \{e_1, e_2\}$ , where  $e_1$  is the internal agency, and  $e_2$  is the local government. Actor  $e_i$  has the ability to handle with  $\Phi_i$ , the ability field, where  $\Phi_1 = \{\theta_1, \theta_2\}$  and  $\Phi_2 = \{\theta_3, \theta_4\}$ . Actor  $e_i$  has the capability  $R(e_i) \rightarrow [0, 1]$ , and if it attempts to handle event  $\theta_j$  completely, it has to lose capability  $C(\theta_j) \rightarrow [0, 1]$ . In order to balance demand and supply, the total amount of capability of actors is supposed to be equal to the total amount needed to finish  $\Theta$ ,

$$\sum_i R(e_i) = \sum_j C(\theta_j) \tag{1}$$

Let  $b_{ji}$  be the ability that  $e_i$  decides to use on  $\theta_j$ , where  $\sum_j b_{ji} \leq R(e_i)$ ,  $i \in \{1, 2\}$  and  $j \in \{1, 2, 3, 4\}$ . Therefore, when  $e_i$  chooses to spend  $b_{ji}$  on  $\theta_j$ , we have

$$R'(e_i) = \begin{cases} R(e_i) - b_{ji} & \text{if } b_{ji} \leq C(\theta_j) \\ R(e_i) - C(\theta_j) & \text{if } b_{ji} > C(\theta_j) \end{cases} \tag{2}$$

and

$$C'(\theta_j) = \begin{cases} C(\theta_j) - b_{ji} & \text{if } b_{ji} < C(\theta_j) \\ 0 & \text{if } b_{ji} \geq C(\theta_j) \end{cases} \quad (3)$$

where  $R'(e_i)$  is the remaining capability of  $e_i$ , and  $C'(\theta_j)$  is the amount of capability still needed to finish  $\theta_j$ .

The actors have their respective responsibility fields for events listed in Table 1. Here  $\theta_j$  in different positions represents the actor in row has the ability to finish it and the actor in column has responsibility to finish it.

**Table 1.** Ability and responsibility fields of actors

	Responsibility field of actor $e_1$	Responsibility field of actor $e_2$
Ability field of actor $e_1$	$\theta_1$	$\theta_2$
Ability field of actor $e_2$	$\theta_3$	$\theta_4$

According to the roles of actors, actor  $e_i$  has utility field  $\Psi_i$ , where  $\Psi_1 = \{\theta_1, \theta_3\}$ ,  $\Psi_2 = \Theta$ . That means the internal agency is just required to finish the events among its responsibility field. But the local government should take care of the whole event set  $\Theta$ .

Formula 1 indicates that if actors could sincerely cooperate with each other, all events could be finished. In that sense, the fragmentation can be evaluated by the completion rate of utility field. For actor  $e_1$ , namely the internal agency, the fragmentation index is

$$F_1 = \frac{C'(\theta_1) + C'(\theta_3)}{C(\theta_1) + C(\theta_3)} \quad (4)$$

For actor  $e_2$ , namely the local government, the index is

$$F_2 = \frac{\sum_j C'(\theta_j)}{\sum_j C(\theta_j)} \quad (5)$$

Typically, the ability filed, responsibility field and utility filed are discrepant for each actor. There is only one exception where  $e_1$ 's responsibility field are the same with its utility filed.

In an urgent situation, actors are limited on their choices. Firstly, actors do not have complete information on  $\Theta$ . Generally they follow the development of situation, and make choices after the event types are certain. The distribution of types among events should be regard as a random process:

$$p(\theta_j) = \begin{cases} \frac{1}{4} & \text{if } j \in \{1, 2, 3, 4\} \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

Secondly, they do not have control on the amount of ability they own. They just spend what they have. Here used the rate of capability to describe the capability allocation between actors:

$$\text{capability rate} = \frac{R(e_1)}{R(e_1) + R(e_2)} \tag{7}$$

Thirdly, in the vast majority of situations they cannot accurately predict the demand of capability,  $C(\theta_j)$ , and have to decide on the event to be first dealt with. Table 2 lists three strategies are summarized to represent actors’ decision process. In strategy 1 and 3,  $e_1$  and  $e_2$ ’s preference is in priority respectively, while in strategy 2, priority is given to actors’ own preference.

**Table 2.** Strategy types given preference of actors

Strategy	Priority of $e_1$	Priority of $e_2$
1	$\theta_1 \succ \theta_2$	$\theta_3 \succ \theta_4$
2	$\theta_1 \succ \theta_2$	$\theta_3 \prec \theta_4$
3	$\theta_1 \prec \theta_2$	$\theta_3 \prec \theta_4$

Note that the responsibility field also has an impact on actors’ preference. The actor should prefer  $\theta_j$  that comes from its own responsibility field. For example, if two  $\theta_j$  both make contributions to improve actor  $e_i$ ’s fragmentation rate,  $e_i$  will prefer the one comes from its own responsibility field.

### 3 Method

#### 3.1 Instantiation of Model

Agent-based simulation system is used to instantiate the theory model. The advantage of this kind of system is that the actors’ preference could be expressed exactly by the behavior of agents.

The total amount of capability owned by actors is 10 units. The capability is distributed to internal agency and local government according to the capability rate which is preset.

$$\text{capability of internal agency} = 10 \times \text{capability rate} \tag{8}$$

$$\text{capability of local government} = 10 \times (1 - \text{capability rate}) \tag{9}$$

Given the capability, the actors will deal with the events according to the strategy set. As the actors could only deal with events among their own ability field, the action sequence is not important.

Table 3 presents four types of events corresponding to Table 1 with new terms for convenience. The first and second letters denote the ability field and the responsibility field respectively, namely, A for internal agency and G for local government. The total number of events is 10 which corresponds to the total amount of capability.

**Table 3.** Four types of events from combinations of ability field and responsibility field

	Internal agency responsibility field	Local government responsibility field
Internal agency ability field	A-A	A-G
Local government ability field	G-A	G-G

According to Table 2, three types of strategy are designed to guide the actors' behavior. Actors are supposed to complete the prior type of event and then the other one if they still have capability. The one with more bargaining power can mobilize capability to its responsibility field, but in a close game, actor can only use its own capability (Table 4).

**Table 4.** Strategy types given the priority

Type	Strategy	Priority of internal agency	Priority of local government
1	Strong internal agency	A-A	G-A
2	Equal power	A-A	G-G
3	Strong local government	A-G	G-G

Fragmentation index is calculated to evaluate the performance of actors for each run. Actors have their respective index. For internal agency,

$$F_a = \frac{\text{Amount of } A - A \text{ Done} + \text{Amount of } G - A \text{ Done}}{\text{Amount of } A - A + \text{Amount of } G - A} \tag{10}$$

If the total number of A-A and G-A type events is 0, the fragmentation rate is 1. For local government,

$$F_g = \frac{\text{Amount of Events Done}}{10} \tag{11}$$

### 3.2 Experiment Design

In order to answer the two questions mentioned in the introduction, A Monte Carlo simulation experiment is used to test: (1) Is the fragmentation phenomenon really created by the simulation system? (2) How does the phenomenon be affected by the combination of strategy type and capability rate?

In each run, simulation system is given a different combination of strategy type and capability rate, and a randomly distributed event group. The actors decide how to cope with events under constrains of the combination. The fragmentation rate is calculated and recorded after actors make decisions. CRN (Common Random Numbers) is used to

reduce the variance of samples, which means each combination is tested by same event groups where each group is randomly created.

### 4 Discussion

Each combination of strategy type and capability rate has been made 1000 independent replications. The boxplots of fragmentation rate of internal agency ( $F_a$ ) and local government ( $F_g$ ) are shown in Figs. 1 and 2, respectively. Here boxplot is used to illustrate the distribution of fragmentation rate given different strategy types and capability rates. Outliers are also marked as dots.

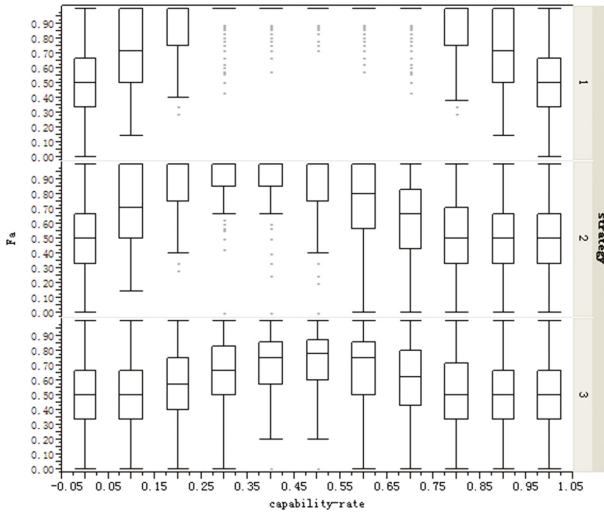
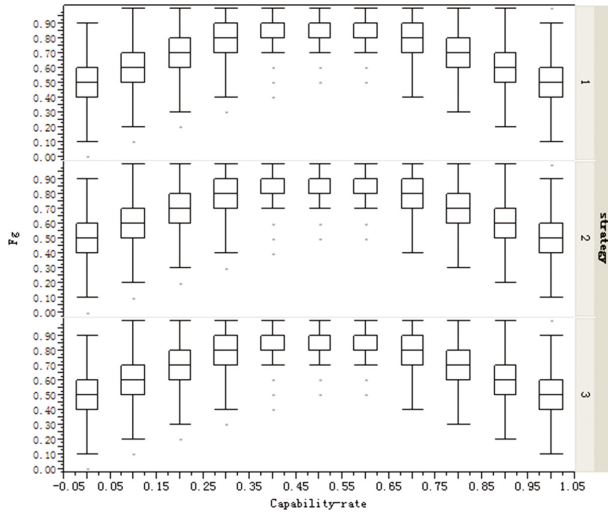


Fig. 1. Comparisons of fragmentation rate of internal agency ( $F_a$ )

Obviously the fragmentation phenomenon happens in all cases. Even in the best case  $F_a$  or  $F_g$  could not reach 1 in a statistical sense. That is  $F_a$  under strong internal agency strategy with capability rate from 0.3 to 0.7. The fragmentation seems almost to be eliminated for  $F_a$ . However, the  $F_g$  in this case looks far away from 1.

Thus a stronger conclusion could be drawn from the experiments: there is no combination could eliminate fragmentation at the same time for both sides. Both  $F_a$  and  $F_g$  do reach 1 simultaneously in some samples. But note the actors have no idea about what would happen next, thus a combination could reach a perfect state by accident does not indicate that it could perform well in other situations.

Another finding is that local government could ignore the bargaining power but pay more attention on the allocation of capability. The performance of  $F_g$  among different strategies appears the same in Fig. 2. Exactly it could be proved that  $F_g$  only can be affected by capability rate and is not responding to strategy. This is because the strategy can only affect the order of events being handled with, and all kinds of events in the



**Fig. 2.** Comparisons of fragmentation rate of local government ( $F_g$ )

utility field of local government, namely the events accomplishment rate or  $F_g$ , can only get the same result given the capability allocation.

This study also finds out the best choices for both sides under each strategy. Table 5 compares the mean and 95 % confidence interval of different combinations of strategy type and capability rate. There are several capability rates that could bring better performance of  $F_a$  or  $F_g$  under given strategy types. Fortunately, there are overlaps of the capability under each strategy. It is very interesting that no matter what the strategy is, the best capability rate seems always to be 0.5, except in strategy 2 where the 0.4 is a better choice to internal agency.

**Table 5.** Mean and 95 % confidence interval of different combinations of strategy type and capability rate

Strategy type	Capability rate	$F_a$	$F_g$	Best choice
1	0.3	$0.9449 \pm 0.0068$	–	
	0.4	$0.9834 \pm 0.0035$	$0.8541 \pm 0.0072$	
	0.5	$0.9943 \pm 0.0019$	$0.8743 \pm 0.0061$	*
	0.6	$0.9861 \pm 0.0033$	$0.8483 \pm 0.0072$	
	0.7	$0.9499 \pm 0.0065$	–	
2	0.2	$0.8590 \pm 0.0109$	–	
	0.3	$0.9300 \pm 0.0077$	–	
	0.4	$0.9270 \pm 0.0091$	$0.8541 \pm 0.0072$	*
	0.5	$0.8547 \pm 0.0136$	$0.8743 \pm 0.0061$	*
	0.6	–	$0.8483 \pm 0.0072$	
3	0.4	$0.7088 \pm 0.0153$	$0.8541 \pm 0.0072$	
	0.5	$0.7304 \pm 0.0147$	$0.8743 \pm 0.0061$	*
	0.6	$0.6866 \pm 0.0158$	$0.8483 \pm 0.0072$	

## 5 Conclusion

In this paper, an agent-based simulation system is constructed to model local government with two actors. One actor is the local government itself, and the other is the internal agency of bureaucracy. The local government is just one node of the whole inter-organizational network of government. Not only the whole network but also the node's structure and operation mode follow the Tiao-kuai structure. In order to discuss the fragmentation phenomenon of crisis governance, the random events set is used to test the performance of local government. And the capability allocation and the capability utilization mode are set as exogenous variables to exclude interference factors.

The simulation experiments showed that the local government with Tiao-kuai structure inside can create fragment of capability by itself during dealing with unpredictable events. The Tiao-kuai structure should be regarded as the basic source of fragmentation, even though other factors may play important roles to make things worse.

The samples revealed three interesting results:

- (1) With Tiao-kuai structure, even with enough capability, there is no way to eliminate fragmentation phenomenon of internal agency and local department at the same time. In fact, only the former could achieve if it is strong enough and does not occupy too much or too little capability.
- (2) Local government and internal agency should pay attention on different aspects. For local government only the capability allocation is important, but for internal agency both allocation and utilization are of vital importance to perform better.
- (3) Even not optimistic, there is still one way to get better performance in terms of fragmentation. No matter what bargaining power the actors have, the capability of crisis governance would be equally split between local government and internal agency. This rule is effective in all kinds of utilization mode.

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