Building New Political Actors

A Model for the Emergence of New Political Actors

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Abstract

The question of the aggregation and disaggregation of political actors is essential for the understanding of the future of global politics, both in terms of international security affairs and international political economy. A model based upon tribute is presented to show how new political actors can emerge from an aggregation of smaller political actors. The tribute model provides an existence proof that it is possible to use simple local rules to generate higher levels of organization from elementary actors. In particular it shows that a dynamics of "pay or else" combined with mechanisms to increase and decrease commitments can lead to clusters of actors that behave largely according to the criteria for independent political states.

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Introduction*

How can new political actors emerge from an aggregation of smaller political actors? This paper presents a simulation model that provides one answer. In its broadest perspective, the work can be seen as part of the study of emergent organization through "bottom-up" processes. In such "bottom-up" process, small units interact according to locally defined rules, and the result is emergent properties of the system such as the formation of new levels of organization. Thus the work is typical of the "Santa Fe" approach to complex adaptive systems (Stein 1989, Fontana 1991, Holland 1992). The concern with increased levels of organization is also reminiscent of how biological systems managed to make the transition from single-celled organisms to multiple celled organisms (Buss 1987), and how brains manage to function by organizing individual neurons into meaningful structures (Hebb 1949, Minks 1985).

The task at hand involves the emergence of new political actors. This is a vital question in the post-Cold War world. We are experiencing an era in which the standard unit of politics, the nation, is no longer completely stable. We see on the one hand, that some states are disintegrating, as in the former Soviet Union and Yugoslavia. We see on the other hand that larger units are being organized, such as the European Common Market, and other regional associations. The question of the aggregation and disaggregation of political actors is essential for the understanding of the future of global politics, both in terms of international security affairs and international political economy.

The question of how the world can be placed on a sustainable path of development is a particularly pressing question. The emergence of new political actors is fundamental to the question of sustainability. One of the main problems of attaining sustainability is the tragedy of the commons (Hardin 1968). The tragedy of the commons arises when many independent actors (people, villages, states, or whatever) each "over-graze" because there is no mechanism to enforce the collective interests of all against the private interests of each. This leads to resource depletion, elimination of bio-diversity, overpopulation, war, and other major social problems. A major route to the prevention of the tragedy of the commons is the emergence of a political actor based upon the organization of previously independent actors. Today we have political actors at the national level that can regulate resource use within their boundaries, but we do not yet have very effective political actors at the trans-national level to regulate resource use at the global level.[1]

Political scientists have a variety of concepts and theories to analyze the emergence of new political actors. Unfortunately, they do not have any formal models that account for this emergence endogenously. In fact, the problem is much like biologists' interest in the emergence of multi-cellular organisms: research has tended to take for granted the existence of such complex units and therefore has not developed rigorous theories to explain how they might have come about in the first place (Buss 1987). For example, the major research paradigm for formal models of politics is game theory, and game theory takes as given exactly who the actors are in a particular setting. In contrast to the rational choice approach of game theory, the model of this paper uses techniques of complex adaptive systems. It takes as given the existence of the lower level actors, and generates higher level actors from the interactions among them.

Given that the goal is to account for the emergence of new political actors, it is important to have a set of criteria which can be used to identify a new actor when one emerges. Here are my criteria for identifying a new political actor as an emergent set of relationships among previously existing units:

1. Effective control over subordinates.
    a. little rebellion
    b. no independent "foreign policy"
2. Collective action ("all for one and one for all")
    a. paternalism: protection of the weak by the strong)
    b. joint foreign policy
3. Recognition by others as an actor

This list is largely inspired by historical and contemporary international law and practice concerning the recognition of new states in the world community of nations. For example, the thirteen colonies became a new nation called the United States when the central government was established which had:

1. Effective control over the individual states:

a. with only low levels of rebellion (at least until the Civil War), and

b. with a prohibition on treaties between the individual states and other nations;

2. Collective control over some important resources:

a. that allowed federal interests to dominant state interests at least in certain important domains, and

b. that allowed for a common foreign policy in matters of war and peace; and

3. Recognition of its independence by other nations such as France and Britain.

While the emergence of the United States is hardly typical, it does illustrate the essential properties of how a new political actor can result from the aggregation of smaller political actors. In the American case, the aggregation was of colonies whose own autonomy was short-lived and precarious during the revolutionary period. The more typical case, and the one modeled here is where the emergent actor is essentially an empire in which a core unit dominates its neighbors. A good example of this process is the growth of the Russian (and later Soviet) empire from a small core around Moscow. Other examples include the growth by accretion of neighboring lands by Rome and China.

Coercion in general and extortion in particular have played a central role in the formation of states over the centuries (Tilly 1985 and 1990). For this reason, at the heart of the present model is the simple dynamic of "pay or else." An elementary actor can make a demand of a neighbor for payment of resources, with the threat that if payment is not forthcoming there will be a war.

In the tribute model wars result in changes in wealth (and thus power), but not in outright territorial conquest.[2] This allows each territory to maintain itself as a separate actor, thereby allowing the for possible emergence of sets of territorial actors who might form a new aggregate actors. Although no territory changes hands, war results in costs to both sides, but especially to the weaker side. Thus the heart of the model is a tribute system in which an actor can extract resources from others through tribute payments, and use these resources to extract still more resources. Alliances are also allowed so that actors can work together. Whether a set of elementary actors actually emerges as a stable aggregate actor will then depend on the dynamics of the tribute system: whether groups of actors actually emerge which function as a single aggregate, and whether alliance patterns emerge which lead to stable coordinated actions.

Unlike my earlier work on the Prisoner's Dilemma (e.g., Axelrod 1984) the tribute model is based upon extortion rather than cooperation. Also, unlike the earlier work it does not assume that the actors are equal in power, but instead the tribute model takes power differences as vital, and as resulting directly from the dynamics of the model. Nor does it assume that the actors interact only two at a time. Like my earlier work, it is not a rational model. The tribute model assumes that actors develop more or less strong commitments to each other based upon their prior actions. These commitments can be thought of as the result of psychological processes (e.g., to stand by those who have helped you in the past), or the result of polticial rules of thumb (e.g., to support those who may later help you in your time of need). Actions are based upon simple decision rules rather than game theoretic calculations of optimal choice, since rational calculations which would be virtually impossible to make in such a complex setting. An important and novel feature is that the behavior of the actors change over time as they apply simple decision rules to data about the historical experience they have gathered through prior interactions.

The project will be successful to the extent that it can account for important phenomena that can't be accounted for by existing formal theories, and can do so with only a few assumptions. The main result to be generated is the emergence of new political actors at a higher level of organization, and the main assumptions have to do with how elementary actors interact with each other. As we shall see, the model spontaneously generates not only emergent actors, but also other interesting phenomena that exist in the world of international politics.

The Tribute Model

The basic units of the model are ten actors arranged on a line. The actors can be thought of as independent political units, such as nations. The reason for having so few actors and having such a simple geography as a line (rather than a two dimensional space) is to keep the data analysis as simple as possible. As long as no vital conceptual features are lost, simplicity is the best modeling strategy. To avoid introducing arbitrary distinctions between actors on the ends of the line and those in the interior, the line is wrapped around into a circle. This gives each of the ten actors exactly two neighbors.

There is one resource in the model, called wealth. Each actor is given some initial wealth. The initial wealths are chosen from a uniform distribution between 300 and 500. These parameters, like all the others in the model are somewhat arbitrary and are selected for convenience.

The basic cycle of the model is called a year. In each year, three actors are chosen one after an other at random to become active. An active actor, A, may demand tribute from one of the other actors, B. Initially, the target, B, must be a neighbor, but later this restriction will be relaxed when alliances are considered. The model is based upon a dynamic of "pay or else." The target, B, then has a choice of paying tribute to the demander, or fighting.

The selection of actors to be active is based upon the notion that ambitious leaders and potential disputes arise at random. But once given an opportunity to make a demand, the activated actor need not actually make a demand if it finds that the current situation is not favorable.

If A does make a demand, the target B has a choice.

* If B pays, wealth is transferred directly from B to A. The amount of wealth transferred is 250 if B has that much. Otherwise, the amount transferred to A is whatever B has. This transfer represents tribute that B pays to A to avoid a fight.[3]

* If B fights rather than pays, each side loses 25% of the <u>other</u> side's wealth (or both lose proportionally less if either side doesn't have that much wealth).[4] This is a simple Lanchester attrition dynamic (Lanchester 1916; Epstein 1985). The idea is that in a fight both sides suffer, but the stronger side imposes more damage than the weaker side does.[5]

After the three activations, the yearly cycle ends with a "harvest" which increases each actors' wealth by 20. This feeds some new wealth into the system. A typical run is 1000 years.

The next question to consider is decision rules used by the actors for making and responding to demands. It would be virtually impossible for actors to develop fully rational rules in the tribute game because of its complexity over time and space. Therefore the model uses heuristic decision rules that capture some of the key short term considerations facing the players.

* The active actor needs to decide whom, if anyone, to make a demand of. The ideal target of a demand is weak enough so that it might choose to pay rather than fight, and so that it won't cause much damage if it does choose to fight. On the other hand, the ideal target should be strong enough to be able to afford to pay as much possible. A suitable decision rule combining both of these considerations is to choose among the potential targets the one that maximizes the product of target's vulnerability times its possible payment. The target's vulnerability is $(W_A-W_T)/W_A$ where W_A and W_T are the wealths of the active actor and the target, respectively. The target's payment is how much the other side can pay, which is the maximum of its wealth and the full

tribute of 250. If no potential target has positive vulnerability (i.e., no potential target is weaker than the demander), then no demand is made.

* The decision rule used for the target is simpler: fight if and only if it would cause less than the paying would.

So far, the model has considered only pairwise interactions. But in order to study the development of emergent actors, there has to be a way for the basic actors to work together. The key idea is that actors develop degrees of commitment to each other. These commitments are caused by their choices to pay or fight, and in turn have consequences for how they will pay or fight in the future. The basic idea is that if two elementary actors fight, another adjacent actor will join the side to which it has greater commitment. If it has equal commitment to the demander and the target, it stays neutral. If it does join one side or the other, it contributes forces (i.e. wealth) in proportion to its commitment to that side.

Initially, no one has any commitments to others, and each actor is fully committed to itself. Commitment of i to j increases when:

a) i pays tribute to j (subservience),

b) i receives tribute from j (protection), or

c) i fights on the same side as j (friendship).

Similarly, commitment decreases whenever:

d) i fights on the opposite side as j (hostility).

The motivation for these rules of commitment dynamics are simple. When one actor pays tribute to another, it is also likely to be partially under its political domination, and therefore compelled to assist it next time. A state typically becomes committed to helping the patron whether by choice or necessity, as illustrated by the participation of many Latin American states in World War II after Pearl Harbor. Conversely, the protection of states that have provided benefits is also commonplace, so as to protect future sources of revenue. The next point is that if two sides have fought together in the past, they tend to be partially committed to each other in the future, as in case of the United States and South Korea after the Korean War. On the other hand, two states that have fought each other are less likely to support each other in the future, as in the case of Germany and France after World War I.[6]

The model assumes that increases and decreases of commitment are in constant amounts, namely increments of 10%. In addition, one actor's commitment to another can never be more than 100% nor less than 0%. The commitment processes described above maintain the symmetry of commitment. This is because two actors start with no commitment to each other and their commitments to each other always grow and decline in unison. For example, if two actors fight on the same side in a war, then their commitment to each other will increase by 10%.

The final part of the model deals with coordination of actors. To keep interactions similar to land combat, coordinated action is assumed to require contiguity. Thus an actor is an eligible target for a demander only if everyone between them joins the demander. Others may then join the demander or the target if everyone closer to that side also joins that side. For example, the actor in position 5 may make a demand on actor 8 only if actors 6 and 7 join actor 5. This requires that actors 6 and 7 are both more committed to 5 than to 8. Then, if 5 does make a demand on 8, actor 10 may join the defense of 8 only if 9 joins too.

Commitments and wealths are common knowledge.[7] Thus when an active actor is evaluating the vulnerability of an eligible target, it can take into account the commitments and wealth of all actors who would join either side. Likewise, the target of a demand can determine the cost to itself of fighting by calculating the damage that the attacking alliance could do, and the proportion of that damage that the target would suffer which is the proportion of the defending alliance's wealth contributed by the defender.

The Dynamics of the Tribute System

Like any stochastic simulation, the tribute model needs to be run many times to explore the type of histories it generates. In the case of the tribute model there are two sources of random variation: the initial wealths of the actors, and the selection of three actors each year to become active. A good way to begin to appreciate the dynamics of the model is to look at history from the perspective of a single actor, say actor 5. This reveals the sequence of events (demands, payments, and fights) that it takes part in. The history also illustrates how alliances are built up from the events that cause commitments.

For example, here is the first few years of history for actor 5 in the first run. In year 9, 5 was active and made its first demand, a demand on a neighbor, actor 4. Finding payment would be more costly than fighting, 4 chose to fight. In the resulting fight each lost wealth, but the defender was weaker and thus lost more than the attacker. In the next year, 5 was again active, and again made a demand on 4. Having been weakened by the previous fight, this time 4 found it cheaper to pay tribute. The payment not only helped 5 at the expense of 4, but lead to a mutual commitment of subservience and protection between 4 and 5 at the 10% level. The next time that 5 became active (year 11), it was able to make a demand of 3 (with 4's support). 3 chose to pay, making it too partially committed to 5. In year 14, 5 became active again and targeted 2. However, 2 refused to pay so 5 fought with the help of 3 and 4, both of whom were partially committed to 5. Since 3, 4 and 5 all fought on the same side they each became 10% more commitment to the others. And since they each fought on the opposite side of 2, they would have become 10% less committed to 2 had they had any commitment to 2.

Having looked at some event-by-event history, it is time to examine the big picture. Figure 6-1 shows the wealth of each of the ten actors over the long time span of 1000 years. The figure clearly shows that three actors were wealthier than the others over most of the history, with actor 5 reaching the highest wealth. A close examination of the figure also shows that something dramatic happened near the end of the 1000 years: a sudden decline in all three of the wealthy actors, especially in the biggest one. Figure 6-2 shows the number of fights in every 25 year period, and also shows the total wealth of the entire population over time. There were many fights at the start but then fewer, with a resurgence of fights in the last 100 years. The resurgence of fights corresponds to the collapse of the population's wealth at around year 900. This kind of major collapse happened only once in five runs of the model.

Figures 6-1 and 6- 2 here.

Quite different histories were generated for new populations simulated under the same conditions. For example, Figures 6-3 and 6-4 show that the second population had four successful actors (rather than three), no fights at all after year 200 (rather than continuing fighting and a late resurgence), and a steady growth of global wealth (rather than a collapse). Figures 6-5 and 6-6 show the third population had two wealthy actors, an uneven pattern of fights, and several moderate declines in global wealth. The fourth and fifth populations showed still other combinations of number of wealthy actors, frequency of fights, and trends in population wealth. Thus, five runs of the same model with the same parameters give quite different histories.[8] Different combinations of initial wealth and the order in which actors become active can evidently make a large difference in the development of the history of the system.

Figures 6-3, 6-4, 6-5 and 6-6 here.

Still another way of looking at the dynamics of the model is to examine the development of patterns of commitment. Typically the first pattern to emerge was a set of proximity relationships in which actors developed low levels of commitment to neighbors, and sometimes to neighbors of neighbors. This pattern is illustrated with the pattern of commitments in year 25 of population 2 (see Table 6-1). The other common pattern of commitments develops after this, and consists of two clusters of actors. A <u>cluster</u> can be defined at a set of actors who all of whom are highly committed to each other (say at the 50% level). Table 6-2 shows the same population twenty five years later divided neatly into two clusters, with no commitments at all between members of different clusters.[9]

Tables 6-1 and 6-2 here.

To see how this population can become divided so quickly into two distinct clusters look at the sequence of payments and fights involving a single illustrative actor, actor 5. Table 6-3 shows the fights and payments involving actor 5 from year 25 when it had only one partial commitment, through year 50 when was fully integrated into a cluster of four actors. The events of year 35 can serve to illustrate the dynamics of commitments that lead to the development of distinct clusters. In that year, 3 and 4 fought 5, 6, and 7. This led 5 to increase its commitment to 6 and 7 while decreasing its commitment (if any) to 3 and 4. In general, as fights take place, they increase the commitments of those fighting on the same side, and decrease commitments of those fighting on opposite sides. Thus as clusters begin to form, then tend to get even more distinct. This is because pairs of actors who fought together became even more committed to each other, and pair on opposite sides lost whatever partial commitment they may have had to each other.. By year 45, fights were taking place that involved all ten actors, leading to the pattern of two strong and distinct clusters that was shown in Table 6-2.

Table 6-3 here.

Having seen how commitments can lead to clusters in an illustration from population 2, let us now return to the unusual case of population 1 where the strongest actor collapsed. The dynamics over the full 1000 years was shown in Figures 6-1 and 6-2. Now we can look in detail at the period of collapse between that took place between years 890 and 950. This is shown in Figure 6-7. In year 911, actor 10 targeted actor 9, resulting in a "world war" involving actors 5-9 versus all the others. Actor 5, the strongest actor, joined in even though it had minimal commitment to 9 since it had none at all to actor 10. Because 5's commitment to 9 was only at the 10% level, it contributed only 10% of its forces to the fight and suffered only slightly. But later that same year, 9 again attacked 10, and this time when 5 joined in it contributed 20% of its forces (having become a little more committed to 9 as well as all the others in that alliance), and suffered a little more. Now 5 was even more committed to everyone in its emerging cluster of 5-9. In years 915-918 there were five more "world wars" with the same alignments (although different demanders and targets). As both sides became more committed to the members of their own emerging clusters, more and more forces were committed and more and more damage was done. The result was a sharp decline in the wealths of the largest actors (5 on one side and 2 and 4 on the other).

This dramatic decline of the strongest actor is due to its being dragged into fights involving weak actors to whom it had developed commitments. This is reminiscent of what happened to two dominant powers, the Hapsburgs in the seventeen century, and Britain in the nineteenth to twentieth centuries. Paul Kennedy has an apt term for the dangers of the excess commitments that strong powers tend to take on. It is "imperial overstretch" (Kennedy 1987). This is just what is illustrated in Figure 6-7. It is striking that a simple model developed to generate new political actors produced behavior that has been the subject of a major policy debate in contemporary international affairs (e.g., Nye 1990).

Figure 6-7 here.

Clusters are not only settings for mutual commitment; they are also settings for extraction of tribute. The strongest actor in a cluster typically stays strong and grows by making demands and collecting tribute from the other members of its cluster. As actors slowly grow due to their annual "harvest", the strong member makes demands upon the weak and reduces their wealth. In fact as the strong member selects lucrative targets, its demands automatically tend to be rotated among members of the cluster. This rotation has the unplanned consequence of preventing any target from growing very strong. But sometimes a weak member of a cluster escapes demands just long enough to grow sufficiently strong enough to make its own demands on still weaker members. If luck lets it be active often enough at this critical stage, it can collect sufficient tribute so that the strongest member no longer finds it advantageous to challenge the newly wealthy actor. An example of this process occurred after year 100 in population 3 (See Figure 6-8). In this example, actor 5 has managed to grow in the shadow of the strongest actor of its cluster, actor 7.

Figure 6-8 here.

Demands within clusters do not always get resolved by payments for tribute. In fact, civil wars can occur, i.e. fighting among members of the same cluster. The strongest member of a cluster is typically strong enough to prevent such a fight from taking place if it took sides. If, however, the strongest member is equally committed to the attacker and the defender (perhaps by being totally committed to both), then it would stay neutral. This allows civil wars to occur if the active actor finds a lucrative target within the same cluster, and the target finds it more costly to pay tribute than to fight. The attacker and defender may even find allies among the others if the others are not equally committed to the two sides.

Surprisingly, initial differences in wealth do not matter for wealth in the long run. In five populations of the model there were fifty actors in all, fourteen of whom were quite successful, using a criterion of wealth of over 10,000 after 1000 years. Of these fourteen successful actors, half had less than average initial wealth and half had more than average initial wealth. One might expect that initial wealth would be a great advantage since it would allow an actor to make successful demands on its neighbors at first, and thereby build up a dominant position in a cluster. But having substantial initial wealth can also make an actor a lucrative target for other strong actors. In addition, having substantial initial wealth can make one overconfident, given the limited rationality of the decision rules in effect.[10]

The results of the model's performance can now be summarized in terms of six characteristics:

1. <u>Things usually don't settle down</u>. Instead, the history of the model shows considerable complexity. For example, as late as year 900, one of the populations suffered a series of fights that destroyed over three-fourths of the global wealth (see Figure 6-2).

2. <u>Histories show considerable variability</u>. The combinations of wealthy actors, frequency of fights, and trends in population wealth differ considerably from one population to another. Even though each actor is using the same decision rules, the results differ greatly due to random differences in initial wealth and in the order in which actors become active.

3. <u>"Imperial overstretch" can bring down even the strongest actor</u>. As an actor becomes committed to others due to tribute relationships and fighting together, it becomes exposed to the risks of whatever fights the others get into. Since actors decide on demands and responses based upon their own calculations, even a weak actor can choose

to make or resist a demand for its own reasons, and thereby drag into the struggle a strong actor who is committed to it.

4. Civil wars can occur among the smaller members of a cluster. While the strongest member of a cluster can typically prevent a fight among members of the same cluster by taking sides, it would not do so if it had equal commitment to the two sides. Therefore, smaller members a cluster may fight each other while the strongest member stands aside.

5. A cluster can have more than one powerful member. Clusters are often like empires, with one powerful actor and many weaker ones who pay tribute to it. But as we have seen in the case of Figure 6-8, it is also possible for a second actor to grow strong in the shadow of the first.

6. Initial endowment doesn't guarantee or even predict success. Before clusters of commitments are established, wealth can be as much a handicap as an asset. The reason is that wealth makes an actor a lucrative target for other strong actors, and can make one overconfident in making demands.

Have New Actors Emerged?

Returning to the original goal of the project, we can now assess the extent to which the emergent clusters of mutually committed actors are really new actors at a higher level of organization. Recall that a cluster is defined as a set of actors who are each committed to the others at a level of at least 50%. This definition provides a set of candidates who may or may not be emergent political actors. To see if clusters actually behave as newly emergent political actors, we return to the original set of criteria.

1. Effective control over subordinates

a. In the simulation, clusters exhibit no rebellion. There were no fights in a cluster against the strongest member. Note that this result is not built into the model's assumptions. After all it would certainly be possible for several members of a cluster to join in attacking the strongest member. (There were however some fights among the secondary actors within a cluster, tolerated by the strongest.)

b. Independent "foreign policy" occurred on only rare occasions. On these rare occasions, the strongest member was dragged into trouble by commitment to a client ("imperial overstretch").

2. Collective action ("all for one and one for all")

a. The strong did protect the weak.

b. Members of a cluster did act together with respect to outsiders, both in attack and defense.

3. Recognition by others as an actor did occur since joint action of clusters was foreseen and taken into account by outsiders. Note that the model assumes that everyone can anticipate the effect of current alliances. The fact that clusters were stable means that the short term calculation based on alliances was tantamount to long term recognition of emergent actors based upon stable clusters.

In sum, the tribute model did produce clusters of mutual commitment, and these clusters did exhibit to a high degree all the attributes of an emergent new political actor. In fact, even the exceptions reflected the kind of exceptions present in international affairs, as illustrated by imperial overstretch.

Variations of the Model

One of the advantages of a simulation model is that it is relatively easy to answer "what if" questions about the effect of varying the parameters or the premises of the model. Here is a very brief sample of some of these questions, with answers based on further simulation runs.

1. Does the model settle down after 1000 years?

No. Even in runs up to 10,000 years there are repeated large wars, and strong actors continue to rise and fall.

2. Are there better decision rules?

Yes. An example is adding a constraint so that a demand won't be made of a target who would find it cheaper to fight than to pay. An individual using this revised rule does much better than the others. Moreover, if every one is using the revised rule, any single individual who uses the old rule would does worse than the others.

3. Does it pay to give and receive commitments?

Yes. An actor who neither gives nor receives commitment does very poorly. Moreover, if just one actor gives and receives commitments (and the others do not, except with that actor), then that actor does very well.

4. What happens if everyone can reach everyone else (as in sea power)?

In this extreme case, a single powerful actor tends to dominate, and there are relatively dense patterns of commitment. Presumably in a two-dimensional space, where everyone has more neighbors than in a one-dimensional space but fewer than in the "sea power" case, there might be an intermediate level of dominance and density of commitment.

5. What if wealth doesn't enter into any one's calculations?

If the demands are made without regard to wealth, and if everyone always fights, then the result is two clear clusters, one of which has virtually all the wealth.

6. Do "islands of commitment" grow?

Yes. If two adjacent actors initially have just 10% commitment to each other (and all other commitments are zero), then these two actors develop complete commitment to each other, and both tend to prosper.

Conclusion: Building Stepping Stones to Theory

The tribute model provides an existence proof that it is possible to use simple local rules to generate higher levels of organization from elementary actors. In particular it shows that a dynamics of "pay or else" combined with mechanisms to increase and decrease commitments can lead to clusters of actors that behave largely according to the criteria for independent political states.

Like most simulation models, the tribute model generates huge amounts of historically rich data. Indeed, a major challenge in any simulation study is to find ways of analyzing and presenting data that help us see the forest for the trees. The present paper illustrates four different kinds of historical analysis. In effect, these are four different ways of looking at history.

a. history from the point of view of a single actor: plots of relative wealth of individual actors over time,

b. history from a global point of view: joint plots of wealth and number of fights over time,

c.. history from the point of view of the emergence of new actors: commitment matrices revealing emerging clusters of actors, and

d. history as "news": event data, including chronologies of tribute payments and wars fought between alliances.

Perhaps the most useful outcome of a simulation model is to provide new ways of thinking about old problems. In the present case, the need to determine whether or not the model was successful in generating new political actors forced the specification of explicit criteria for recognizing a new political actor should one arise. This in itself is a useful exercise. In addition, the same need led to the development of different ways of viewing history, and especially in ways of analyzing the interaction among emerging clusters of actors.

In the future it would be good to use these conceptual and statistical developments to answer some new questions suggested by the model. For example, the dynamics we have seen in the tribute model suggest the following interesting questions:

a. What are the minimal conditions for a new actor to emerge?

b. What tends to promote such emergence?

c. How are the dynamics affected by the number of elementary actors?

d. What can lead to collapse of an aggregate actor?

e. How can new actors grow in the shadow of established actors?

While no one would believe that the answers to these questions given by the model itself would necessarily be accurate for the real world, a realistic hope is that the concepts developed in generating the answers for the model would be useful in providing new ways of thinking about comparable questions in the real world. Indeed, understanding the dynamics of the tribute model might also suggest specific hypotheses that could be tested with data from the real world. In addition, the study of one model, such as the tribute model, can provide the basis for insights into how even simpler models can be developed that might allow deeper insights into issues of emergent political organization.

Finally, a simulation model like the tribute model can lead to insights into where there might be policy leverage in the real world. For example, one might be able to identify situations in which slight changes in the system could lead to substantially improved outcomes - in terms of fewer destructive wars or greater coordination of political action. If we knew when minor inputs could lead to major gains we would have valuable clues to consider for policy leverage in the real world - the world where avoiding war and achieving sustainability really matter.

References

Axelrod, R. 1984. The evolution of cooperation. New York: Basic Books.

________ & D. S. Bennett 1993. A Landscape Theory of Aggregation. British journal of political science, 23: 211-233. Included as Chapter 4 of this volume.

Bueno de Mesquita, B. and D. Lalman 1992. War and reason : domestic and international imperatives. New Haven : Yale University Press.

Buss, L. W. 1987. The evolution of individuality. Princeton, NJ: Princeton University Press.

Cusack, T. R. & R. J. Stoll 1990. Exploring realpolitik: probing international relations theory with computer simulation. Boulder CO: Lynne Rienner.

Epstein, J. M. 1985. The calculus of conventional war: dynamic analysis without Lanchester theory. Washington, DC: Brookings.

Fontana, W. 1991. Functional self-organization in complex systems. In 1990 lectures in complex systems, SFI studies in the sciences of complexity, vol. III, L. Nadel and D. Stein (eds.), 407-426. Redwood City, CA: Addison-Wesley.

Hardin, G. 1968. The tragedy of the commons. Science, 162: 1243-1248.

Holland, J. H. 1992. Complex adaptive systems. Daedalus 121:17-30.

Hebb, D. O. 1949. The organization of behavior. New York: Wiley.

Huth, P. 1988. Extended deterrence and the prevention of war. New Haven: Yale University Press.

Kennedy, P. 1987. The rise and fall of the great powers. New York: Random House.

Lanchester, F. W. 1916. Aircraft in warfare: the dawn of the first arm. London: Constable. Key chapters reprinted as: Mathematics in warfare. The World of Mathematics, J. Newman (ed.) 1956. New York: Simon and Schuster.

Minsky, M. 1985. Society of the mind. New York: Simon and Schuster.

Nye, J. S., Jr. 1990. Bound to lead, the changing nature of American power. New York: Basic Books.

Powell, R. 1990. Nuclear deterrence theory : the search for credibility. Cambridge and New York: Cambridge University Press.

Schelling, T. 1960. The strategy of conflict. New York: Oxford University Press.

Stein, D. L. (ed.). 1989. Lectures in the sciences of complexity. Redwood City, CA: Addison-Wesley.

Tilly, C. 1985. War making and state making as organized crime. In Bringing the state back in, P. B. Evans, D. H. Rueschemeyer and T. A. Skocpol (eds.), 169-191. Cambridge: Cambridge University Press.

_______ 1990. Coercion, capital, and European states, AD 990-1990. Oxford: Basil Blackwell.

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[1]Of course, the ability to regulate resource use does not guarantee that the ability will be wisely used. For example, the former Soviet Union had the power to control pollution from its factories, but in the interests of maximizing production it chose not to exercise that power.

[2]This contrasts with Cusack & Stoll (1990) whose simulation model uses conquest of territory as the major dynamic.

[3]Having a fixed maximum demand is arbitrary, but avoids the need for the actors to calculate what demand they will make.

[4]For example, if A has 400 and B has 300, A loses .25*300=75, and B loses .25*400=100. The wealths after the fight would then be 400-75=325 for A, and 300-100=200 for B. Note that the disparity in wealth increases from 100 to 125. If B began the fight with only 50, then B would lose all 50 (which is half the other damage A is capable of doing), and A would lose half of the maximum damage B is capable of causing, i.e. .25*.50*50= 12.5.

[5]The demander is assumed to carry out its implicit threat to fight if the demand is not met. This assumes, in effect, that the demander's need to maintain its reputation is strong enough to maintain the credibility of the threat.

[6]For evidence on the friendship and hostility aspects, see Axelrod & Bennett (1993).

[7]In international politics, wealth can usually be estimated with rough accuracy, but commitments are harder to predict. There is a rich empirical and theoretical literature on

commitment. See for example Schelling (1960), Huth (1988), Powell (1990), Bueno de Mesquita & Lalman (1992), and Axelrod & Bennett (1993).

[8]A run takes only 23 seconds on a Macintosh Quadra 700 using Pascal. Of course, the analysis can take days or weeks.

[9]In many cases, there were two large clusters with one or two actors participating in both of the clusters.

[10]For example, suppose an actor with wealth of 500 makes a demand on a neighbor with 400. The neighbor will fight rather than pay (losing .25*500=125 which is less than payment of the standard demand of 250). Since the target fought, the demander loses .25*400=100, and is worse off by having made the demand. Had the initial wealths been greater than 1000, this would not happen since the cost of fighting would be greater than the standard demand of 250.

FIGURE 1.
Wealth of Each Actor Over 1000 Years (Population 1).

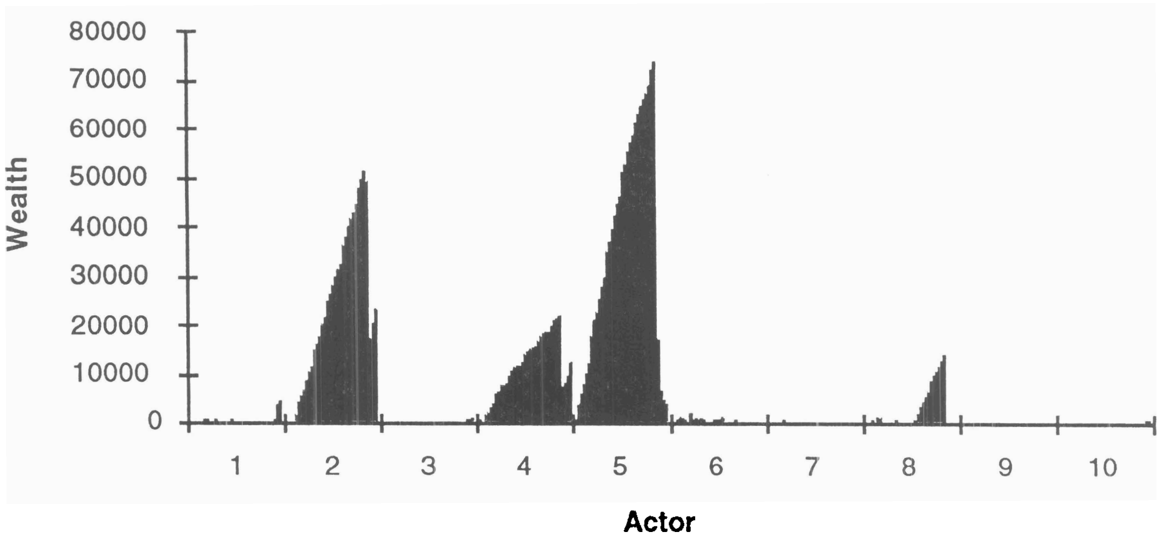

FIGURE 2.
Fights (bars) and Population Wealth (line)
in Population 1

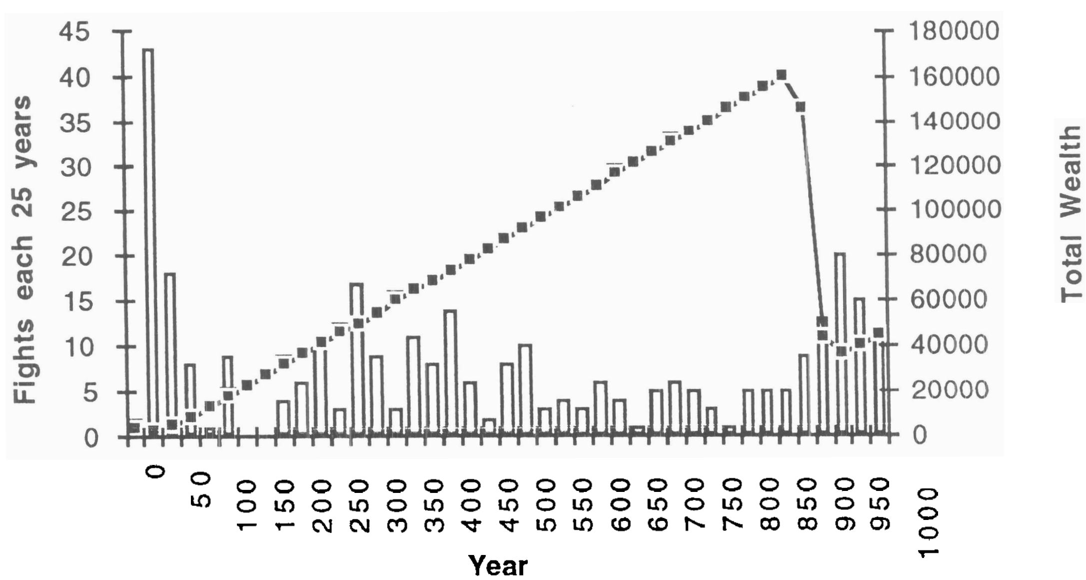

FIGURE 3.
Wealth of Each Actor Over 1000 Years (Population 2).

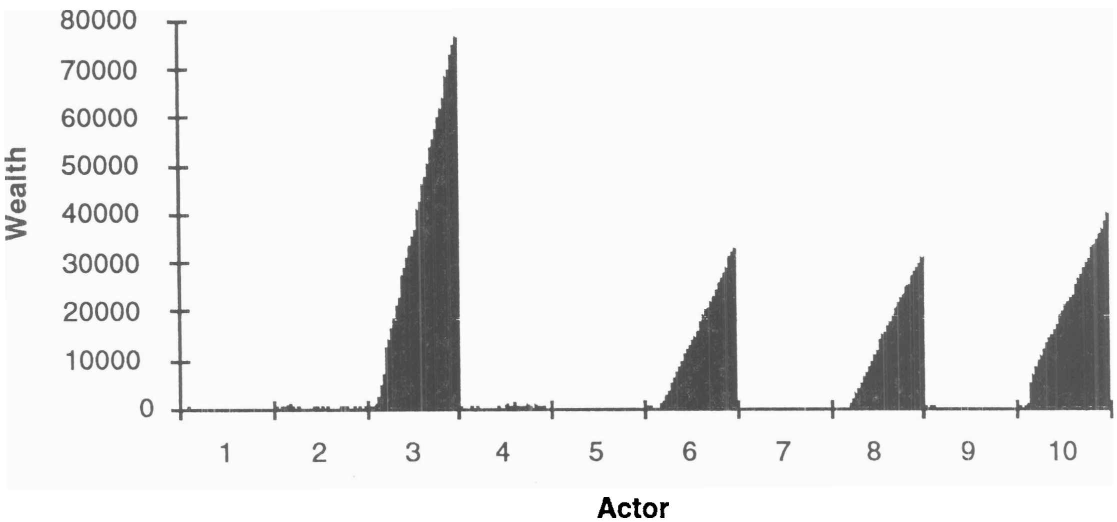

FIGURE 4.
Fights (bars) and Population Wealth (line) in Population 2

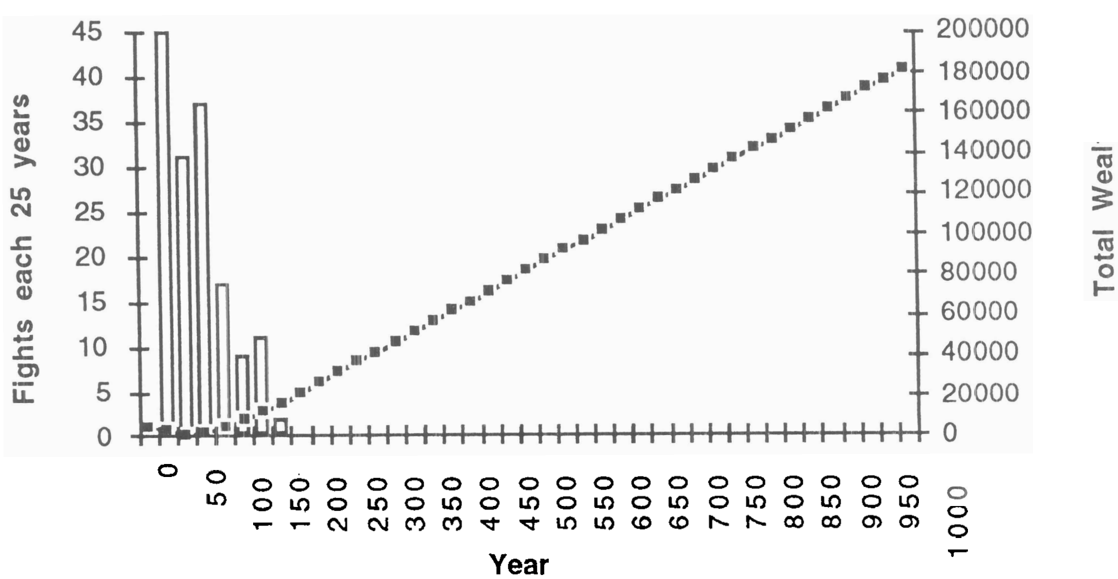

FIGURE 5.
Wealth of Each Actor Over 1000 Years (Population 3).

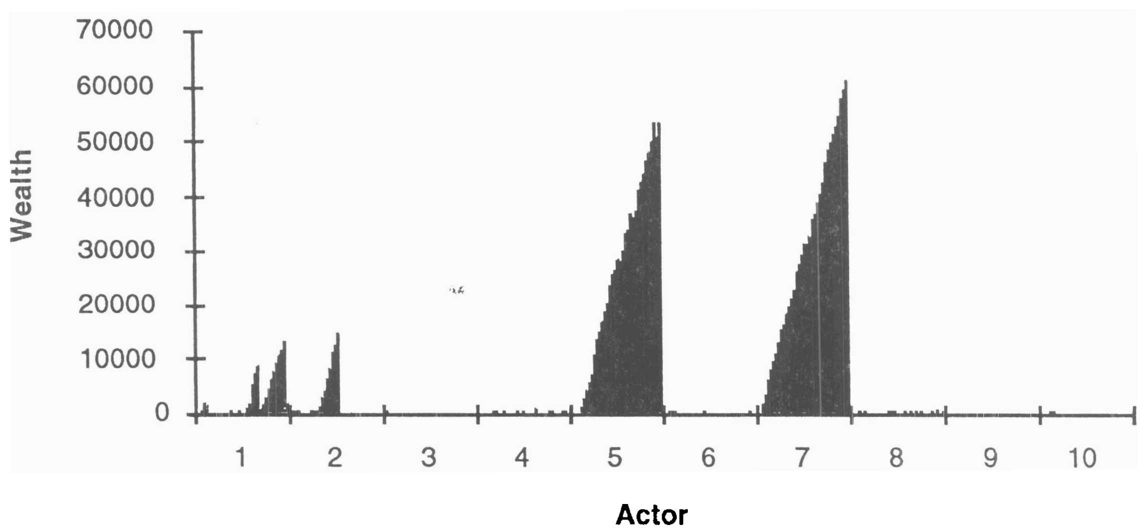

FIGURE 6.
Fights (bars) and Population Wealth (line)
in Population 3

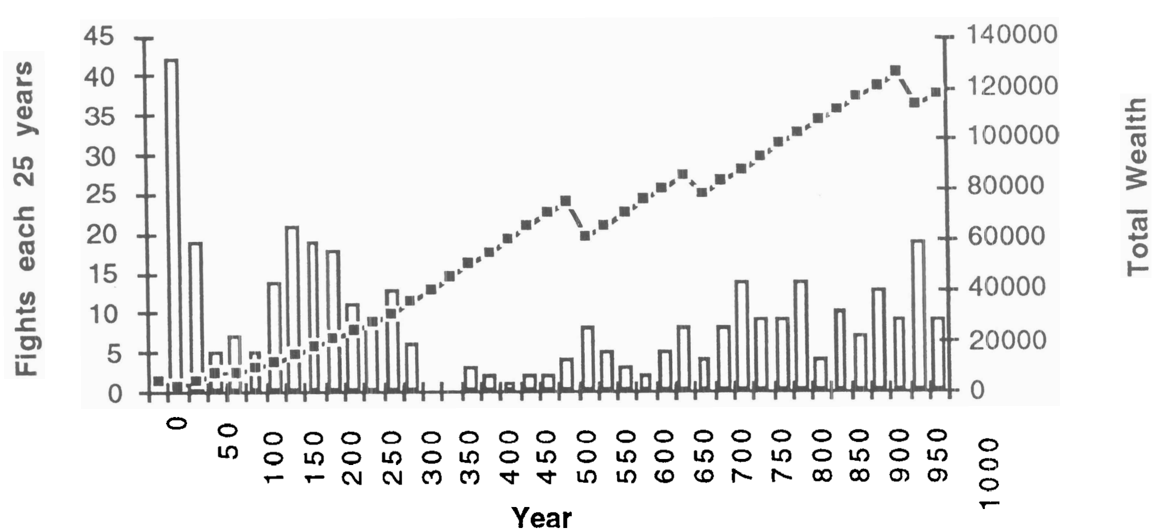

FIGURE 7.
Late Collapse of a Powerful Actor.

Payments and Fights Involving Actor 5 (Population 1, Years 890-950)

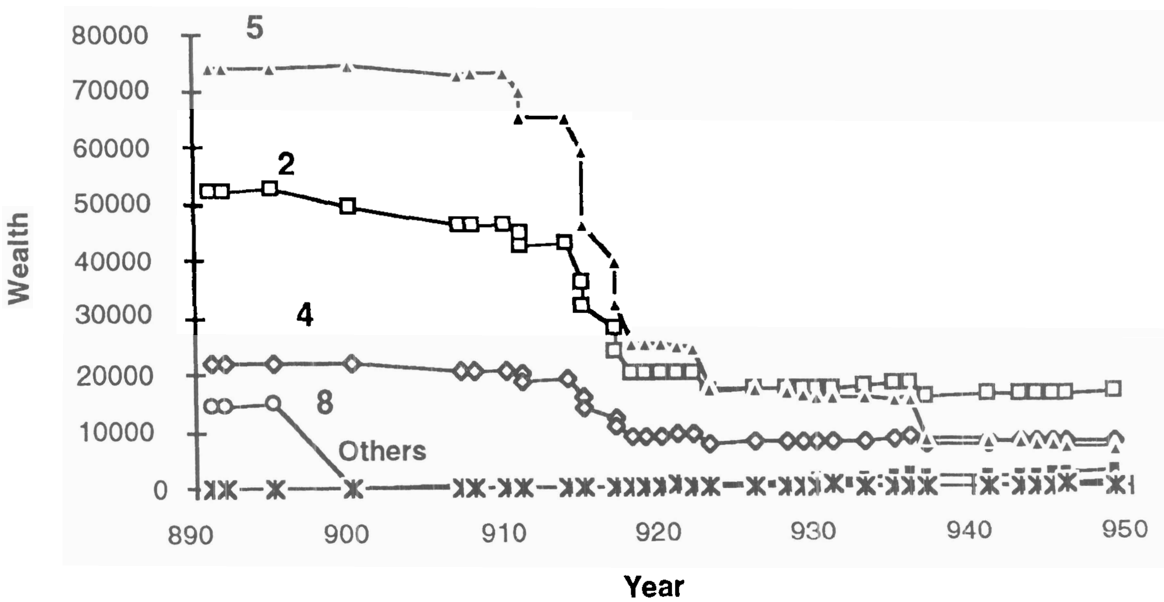

FIGURE 8.
Internal Conflict.

Growth of a Second Strong Actor in a Cluster of Actors 4-8. (Population 3)

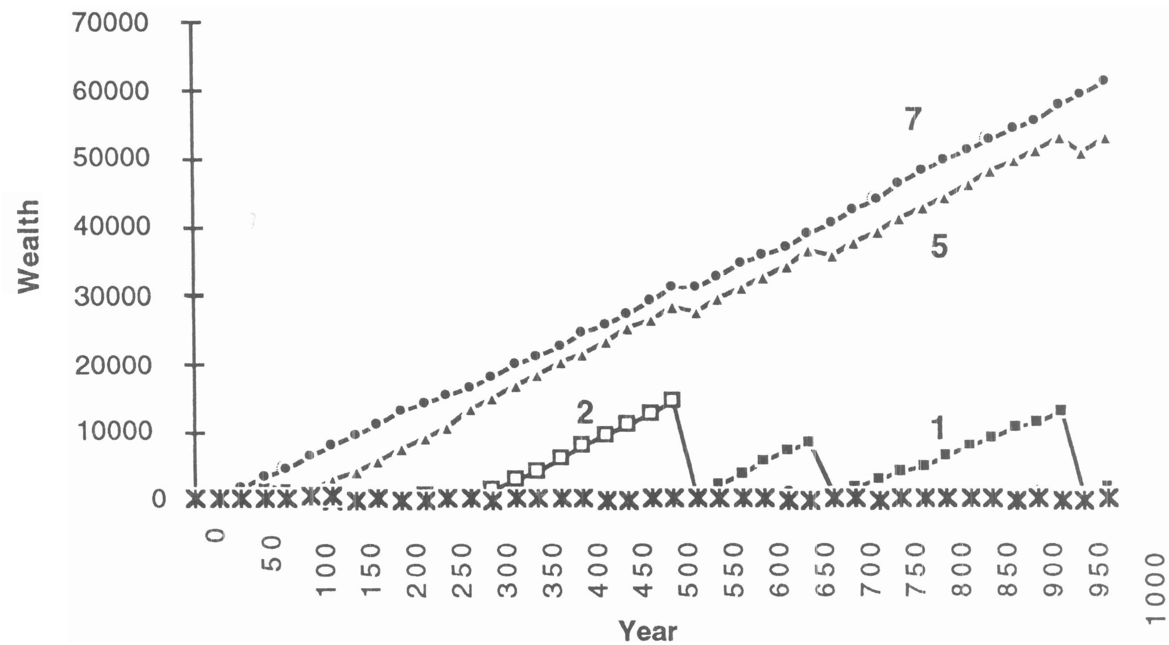

Table 1. Commitments Forming a Proximity Pattern (from Population 2, Year 25).

i, j	1	2	3	4	5	6	7	8	9	10
1	100	30	0	0	0	0	0	0	10	40
2	30	100	0	0	0	0	0	0	20	20
3	0	0	100	20	0	0	0	0	0	0
4	0	0	20	100	30	0	0	0	0	0
5	0	0	0	30	100	0	0	0	0	0
6	0	0	0	0	0	100	0	0	0	0
7	0	0	0	0	0	0	100	0	0	0
8	0	0	0	0	0	0	0	100	50	0
9	10	20	0	0	0	0	0	50	100	10
10	40	20	0	0	0	0	0	0	10	100

Note: Actors 1 and 10 are adjacent.

Table 2. Commitments Forming Pattern of Two Clusters (from Population 2, Year 50).

i, j	1	2	3	4	5	6	7	8	9	10
1	100	100	70	0	0	0	0	100	100	100
2	100	100	100	0	0	0	0	100	100	100
3	70	100	100	0	0	0	0	100	90	70
4	0	0	0	100	100	60	100	0	0	0
5	0	0	0	100	100	100	100	0	0	0
6	0	0	0	60	100	100	100	0	0	0
7	0	0	0	100	100	100	100	0	0	0
8	100	100	100	0	0	0	0	100	100	100
9	100	100	90	0	0	0	0	100	100	100
10	100	100	70	0	0	0	0	100	100	100

Note: Actors 1 and 10 are adjacent.

Table 3. Development of Clusters of Commitments.

Fights and payments involving individual 5 of population 2 between years 25 and 50.

Yr.	Active Actor	Target Actor	Roles	Commitment with actor 5 increases[1]	Commitment with actor 5 decreases[2]
30	4	5	--aAD-----		3, 4
30	6	5	----PR----	6	
32	3	4	--ADd-----	4	3
32	4	5	--aADd----	6	3, 4
33	4	3	-dDAa-----	4	2, 3
34	5	7	----R-P---	7	
35	5	4	--dDAaa---	6, 7	3, 4
36	3	4	-aADd-----	7	2, 3
36	8	7	aa--ddDAaa	6, 7	1, 2, 8-10
37	6	5	----PR----	6	
38	8	7	aaa-ddDAaa	6, 7	1-3, 8-10
38	2	7	aAa-ddDaaa	6, 7	1-3, 8-10
41	8	7	aaa-ddDAaa	6, 7	1-3, 8-10
42	6	5	----PR----	6	
42	5	4	---PR-----	4	
44	5	7	----R-P---	7	
46	7	8	dddaaaADdd	4, 6, 7	1-3, 8-10
47	7	8	dddaaaADdd	4, 6, 7	1-3, 8-10
48	7	3	ddDaaaAddd	4, 6, 7	1-3, 8-10
48	5	3	ddDaAaaddd	4, 6, 7	1-3, 8-10

Key to roles:

A = attacker, a = attacker's ally,
D = defender, d = defender's ally,
P=payer, R = receiver of tributer.

[1]Increases by 10%, up to 100%.

[2]Decreases by 10%, down to 0%.