Adaptation, State Survival and System Endurance: A Simulation Study

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ABSTRACT. This paper reports on a study using the EARTH (Exploring Alternative Realpolitik Theses) Simulation Model. The model is an abstract representation of an anarchic multistate system wherein states employ Realists' principles in guiding their choices on questions dealing with war and peace. The present study examines the systemic and state level consequences that arise in the presence or absence of the ability of states to adapt or change the fundamental decision rules that they employ.

Introduction

This paper extends some of our earlier work that has dealt with the practice of Realpolitik within a multistate system and in particular on the effects of alternative decision-making processes. The focus here is on the state and systemic level consequences that derive from introducing the assumption that states have the ability to adapt their decision-making procedures. We represent adaptation as a higher level organizational process, one that might appropriately be called learning, and we will limit our inquiries here to two fundamental questions: (1) does learning (adaptation) significantly enhance the survival chances of states embedded in an anarchic system?; and (2) does learning (adaptation) affect the overall functioning of the system by improving upon the chances of preventing a hegemon from absorbing the entire system of states?

Our research agenda has combined two related elements: first, we have attempted to formalize many of the principal theses of realism within a model and, second, we have sought to assess the logical implications of the theses through experimental analyses conducted with a computer simulation model. Two broad concerns have shaped the writings and arguments of the Realists, the survival of individual states and the maintenance of pluralism within the system. These two have also guided our research efforts. For example, Stoll (1986) examined the consequences of geographical position, relative power, and power assessment abilities on the survival of individual states, and in a later study, Stoll (1987) went on to examine the potential for power balancing behavior to emerge in a Realist system and to assess the implications of this for the maintenance of system pluralism.

Cusack and Zimmer (1989) examined the effects of a variety of structural...
conditions and policy propensities on the potential for multistate system endurance, and Cusack (1987, 1989) also examined the implications for both state survival and system endurance of the use of alternative power management styles, as well as the effects of the cost of empire maintenance and resource allocation priorities on system endurance. Finally, Cusack and Stoll (1988) and Cusack (1987) studied the implications of the use of rational or expected utility decision logics on the survival chances of states and system endurance.

This paper continues our concern with the implications of alternative decision-making logics. We attempt to broaden that focus by positing the potential existence of adaptation on the part of states. Adaptation is represented as the occurrence of shifts between two different decision-making processes. It is based on two factors: (1) observed differences in the relative success that derives from the use of each process within the system, and (2) state level capacities to affect such a transition.

In the next section we address the theoretical importance of adaptation. Following that, we outline the basic structure of the model used in the analysis of this question and specify the structural changes that have been implemented in order to conduct this study. The fourth section lays out the experimental design of the study and provides an overview of the results generated by our experiments with the model. The last section provides a summary of the principal findings that have emerged from this study.

**Adaptation and the Balance of Power System**

The analogy of the market is often applied by students of world politics to the international system. Both are seen as predatory environments and, in both, a process of natural selection is thought to be one of the principal mechanisms that govern the character of the system and the survival chances of its inhabitants. For some, rational choice is a sine qua non for survival. Indeed, one of the main prescriptions that flow from Realist writing is the need for cool and rational calculation on the part of statesmen. However, we have reasons to believe that in a competitive environment, rationality is not always the superior strategy of decision making. Indeed, organizational theory suggests that the application of other principles may at times prove superior.

But even more critical for understanding the bases of individual success and system maintenance, is the role of flexibility in organization: i.e., flexibility in technique and in the criteria employed in decision making. One of the principal arguments in the behavioral theory of the firm is that organizations are in the short term fixed in their ways and prone to handle decisions on the same basis as they have in the past (Cyert and March, 1963). However, organizational form and functioning can change. They do so through a process whereby significant failure, detected by generating assessments in terms of absolute standards or comparisons with the performance of competitors, is signalled.

Taking this point further, Nelson and Winter (1982) have argued that the dynamics of the marketplace, its tendencies toward or away from concentration, and, at the micro level, the success of individual firms, can best be understood by dispensing with orthodox economic theory's assumption of fixed choice sets and known consequences of choice, and instead employing an evolutionary perspective which assumes that "no choice is clearly the best ex ante," and that through selection and conscious adaptation, good practices are rewarded and bad ones suppressed. In
effect, the set of firms in a market is likely to be diverse in the composition of decision-making processes employed and those that survive in a competitive environment are likely to be those most adept at altering these processes in light of the relative success that attaches to each. A similar thesis is apparent in the Realist theory of Kenneth Waltz (1979).

In our earlier paper on the implications of alternative decision-making logics within an idealized Realpolitik world, we concluded that there was no apparent inherent success for states that employed relatively sophisticated decision-making strategies as opposed to more primitive ones. Our results also suggested that the systemic level consequences of more rational choice practices at the state level were positive—in the sense of helping to preserve system pluralism. In combination, our earlier findings and the direction suggested by heterodox economic theory suggest the potential benefits of exploring the implications of a more complex realization of decision making on the part of states embedded within a competitive system.

In the next section we will briefly describe the basic model used to explore this problem and describe the structural changes to the model that have been implemented to conduct this study.

A Formalization of the Automatic Stabilization Model of the Balance of Power System

THE BASIC MODEL

Our analysis of this problem is conducted with a computer simulation model that is a reconstructed version of a model originally developed by Bremer and Mihalka (1977). This model is a formalization of the “automatic stabilization” image of the balance of power system in a multistate system (Claude, 1962). In brief, the model represents a multistate system with what are considered to be three essential characteristics. The first characteristic refers to the size of the system—that is, the number of sovereign states. In the simulation model as many as 98 states can be represented, though systems of smaller and larger size can also be portrayed. The second essential feature of such a system is the geopolitical character of its units. Each state unit is provided with a distinct territorial domain located in an ordered geographical space. In addition, each unit possesses some degree of military power that is vital to its survival and is subject to growth and destruction. The third and final characteristic relates to the capacity of each of these state units to observe its environment, assess the present situation, engage in decision making, and implement its decisions.

The initial configuration of states is shown in Figure 1. The model incorporates a portrayal of time; actions take place within an iteration of the model. The consequences of these actions help to define and shape the circumstances that confront the state actors in the succeeding iteration. Within each iteration there are four major phases of activity. Three of these four are processes directly associated with war. The first phase determines whether a dispute will occur amongst some system members. In the second phase, the processes of dispute escalation and de-escalation are portrayed. In other words, during this phase decisions are taken by various state actors which determine whether a war occurs and which states will be involved. The third phase deals with the direct consequences of war in terms of assessing costs and transferring gains. In the fourth and last phase the power
Phase 1: Selection of a Potential Dispute Initiator

The objective of this phase is to select from among the existing states that one which has the opportunity to choose a target for aggression. The selection procedure relies on a uniform random number generator and sets each state's probability of selection as the potential initiator equal to its relative share of the total power capabilities in the system. This relationship between initiation and a state's relative power is consistent with empirical evidence that the higher a nation's rank, the greater the likelihood of its involvement in and indeed, initiation of serious disputes and wars (Bremer, 1980; Eberwein, 1982).

Phase 2: Dispute Onset and Escalation

Four stages are included within this phase which is a stylized version of interstate militarized disputes. In the first stage, the potential initiator decides whether to instigate a conflict against a neighboring target state. In the second stage, the target is provided with the opportunity to build a coalition to counter the threat from the initiator. In the third stage, the initiator is allowed to develop a counter-coalition to that of the target, to defer from such an alliance-building effort and continue its aggression, or to terminate the dispute. The fourth stage is contingent upon the
initiator pressing forward and allows the target an opportunity to widen its coalition. War occurs only if the first three stages are traversed (in other words, only when the initiator has twice chosen the war option). The target is limited only to actions which enhance its capacity to counter the threatening power of the initiator (and, where such exists, the initiator’s coalition power). The target cannot, for example, “buy off” its opponent through some concession. Let us look at each of these stages in more detail.

2.a Potential Initiator’s Actions. The initiator state, \( i \), compares its power capabilities with each of its neighbors. These power assessments and comparisons are based on “estimates” subject to “error”:

\[
\text{ESTPOW} = \text{ACTPOW} \times [1 + \text{Nrand(POWeST, ESTSD)}]
\]

The actual power of a state is multiplied by a factor representing the ability of the estimator to evaluate power correctly. This factor is 1.0 plus a random component. The random component is drawn from a normal distribution, using the estimator’s given ability to assess power as the mean and the standard deviation of power estimation ability across all the states in the system as the standard deviation. The initiator takes no action (i.e., activity in this iteration moves to the fourth and last phase, Power Adjustment) if no neighbor is estimated as weaker than itself. If there exist neighbors perceived as weaker, the one assumed to be the weakest is selected as the target. In effect, then, “objectively” weaker states may attack due to error.

2.b Target’s Initial Response. The target compares its own power with the estimated power of its assailant. If the comparison favors the target in that it perceives itself as having more power than the initiator, it takes no further action (model moves to 2.c). An unfavorable comparison leads the target to attempt the construction of a “defensive coalition.” The target will consider only “minimum winning” coalitions of contiguous states. Involved here are three considerations:

1. All possible coalitions of states contiguous to opponent are assayed;
2. the combined power of each such potential coalition is estimated;
3. alliance membership bids are directed toward those states in the group which are contiguous to the opponent and which have more combined power and yet are the least powerful of all such proto-coalitions.

If no such coalition exists, the target state takes no action (model moves to 2.c).

The potential allies—those states contiguous to the opponent, which have received alliance bids—make their decisions independently. In other words, the decision is made without regard to the choice of other potential allies. This decision is based on the potential ally’s own assessment of the estimated power of the proto-coalition in comparison with its estimate of the power of the opponent. Where the proto-coalition is perceived as stronger, the potential ally joins; where it is seen as weaker, the bid is rebuffed and the state stays outside the coalition.

2.c Initiator’s Rejoinder to the Target. Depending upon the target’s success in building a coalition, the initiator acts in the following way:

(a) If target is unsuccessful in acquiring allies, the initiator opts immediately for war;
(b) Where the target has constructed an alliance, the initiator first compares its estimated power with that estimated as under control of the target's coalition. If the initiator sees itself as stronger, it opts for war; otherwise, it engages in the process of attempting to build its own coalition.

Like the target, the initiator seeks a coalition based upon the contiguous minimum winning criteria. If such a coalition is needed and does not exist, the initiator withdraws from the conflict and the dispute is ended. If such a proto-coalition exists, the initiator extends alliance membership bids to the potential members. A state's decision to join or refrain from joining such a coalition is again contingent upon its estimate of the potential success of that coalition. The latter hinges upon the estimated relative power of the two sides. It independently makes the decision to join if the estimated power of the proposed coalition is greater than that of the opponent's. It will independently decide not to join if it estimates the proto-coalition as weaker. If all states invited to join the coalition of the initiator accept the bids, the initiator opts for war; however, if one or more such invitations are refused, the initiator is in a position of perceived weakness vis-à-vis the target and it opts for a termination of the dispute.

2.d Target's Second Round of Coalition Building. If the initiator has opted for war in 2.c, the target compares its assumed power, or the assumed power of its alliance when such has been constructed in 2.b, against that of the initiator's side. If the target sees its side as more powerful, it refrains from attempting to acquire more allies. Conversely, if it sees its side as weaker, it attempts to expand the size of its coalition. Additional members are selected on the bases described in 2.b. States invited to join the expanded alliance act in the same independent way described in 2.b and 2.c. Their actions conclude this phase of the iteration. The next phase of activity deals with the warring process and outcome.

Phase 3 War: Determining the Victor and Distributing the Costs and Benefits

There are four stages to this phase. The first determines the victorious side in the war. In the succeeding stages, the consequences of the war, in terms of costs and benefits, are sorted out. Stage two deals with the determination of war costs confronted by all participants. The succeeding stage focuses on the assessment of indemnities and the fourth and final stage is given over to the processes involved in transferring territorial units.

3.a War's Victor. Three general principles are incorporated in the determination of the war's outcome. First, the model represents war as producing a determinant outcome. That is, every war has a victorious and a vanquished side. Second, all wars end in the period or iteration in which they began. Third, the identity of the victor and vanquished is stochastically related to the relative capabilities of the two sides. The likelihood of victory for the initiator is expressed as a complex function of the ratio of the initiator coalition's capabilities relative to the target coalition's capabilities. The shape of the curve provided by this function is logistic. The exact shape can be controlled by the value of one parameter. It should be noted that the higher the value given to the controlling parameter, the flatter is the shape of the curve in the areas where the two sides are nearly equal.
3.b Common War Participation Costs. Three principles guide the imputation of common war participation costs. First, all participants in the war bear costs. These costs are paid in the currency of power units. Second, all participants, regardless of whether on the victorious or vanquished side, suffer a decrease in power of equal proportion. The total of indemnities contributed by the defeated states is allocated across the member states of the winning coalition on the basis of each member's contribution to the total capabilities of the alliance. Third, the cost function that confronts each participant contains two principal components: (a) a parameter specifying the maximum proportional war costs, and (b) the relative power of the opposing sides. The function takes the following form:

\[ \text{WARCOST} = \left( 1.0 - \frac{(LSR - 0.5)}{0.5} \right) \times \text{WarCostMax} \]

where \( LSR \) is defined as the ratio of the power of the larger side to the sum of the power of both sides in the war and \( \text{WarCostMax} \) is the maximum proportional cost parameter.

3.c Assessment of Spoils (Indemnities). Each actor in the defeated coalition is assessed an indemnity equal to some constant proportion of the power units it possesses. This proportion is meant to reflect the punitiveness (i.e., lack of restraint) on the part of the victor. The total of indemnities contributed by the defeated states is allocated across the members of the winning coalition on the basis of each member's contribution to the total capabilities of the alliance. In addition to the direct transference of power units from the winning to the losing side, a more complicated and potentially more rewarding form of exploitation is provided for in the way of territorial transference from the principal losing state to the victorious coalition.

3.d Assessment of Spoils (Territory). Territorial loss occurs only by the leader (the initial member) of the losing coalition. The amount or size of territorial loss—that is, the distinct pieces of territory lost—is a function of the size of the loser and the “decisiveness” of its loss. The territory taken from the loser is parcelled out amongst the members of the winning coalition on the basis of a proportionality rule with respect to the power units of each member of the coalition. Certain constraints restrict the application of this proportionality rule. Details on the procedure whereby such transference takes places are provided below.

The “likelihood of victory” (LV) function is used to determine the proportion of the losing coalition leader's territorial holdings to be transferred. If the victor is the initiating coalition, the proportion of the loser's territories to be surrendered is the LV score. If the victor is the target coalition, the proportion is equal to 1.0 minus the LV score. The proportion is then multiplied by the number of territories possessed by the loser and the resulting product is rounded to the nearest integer. If, however, the loser possesses only one territorial unit, possession is transferred and the state is eliminated from the system. States with more than one territorial unit can also be eliminated if the magnitude of their defeat, as reflected in the LV score, is sufficiently large.

The territories extracted from the loser are then allocated among the members of the victorious coalition. This is done on a proportional basis with each state's share of the “booty” initially specified as equal to its relative power position within the
victorious coalition. With these preliminary shares specified, the selection of territorial units begins. Certain related rules are iteratively applied to guide it in its selection of a territorial unit. In choosing its acquisitions, the recipient works on acquiring one territorial unit at a time. With its acquisition selected, the recipient begins to select the next unit it is to receive, or retires from the selection process if it has received its quota.

Two rules guide the territorial selection process. The first allows a recipient to choose only units that are contiguous to itself. If the application of this rule produces one such territory, the unit identified is transferred. If more than one unit is identified, a second rule is invoked. This rule chooses from the list of possible acquisitions the unit that leaves the loser with the most compact shape to its overall territorial holdings. It does not aim for a compact shape for the territory gainer.

When one member of the victorious coalition finishes with its selection of new acquisitions, the selection rights move to another member, and so on, until there is no more territory to be divided. The completion of the rearrangement of the map effectively ends the war phase of the iteration.

**Phase 4: Power Adjustment**

This is the last phase of each iteration of the model. Herein, the power in each of the territorial units held by the existing states is increased by a percentage factor. The size of this factor is the same across all states. With this updating completed, the model has passed through a full iteration and moves into a new period.

**TWO DECISION MAKING STYLES**

As in an earlier paper (Cusack and Stoll, 1988), the structure of the basic model has been modified to permit the representation of two different styles of decision making. These two styles are labelled, respectively, primitive power seeking and sophisticated power seeking.

The first style, primitive, is equivalent to that employed in the basic model as described above. Generally, a state endowed with this decision-making style bases its decisions on a single calculation: it estimates the amount of power available to its side and the amount available to the opponent's side. If it calculates that it is stronger than the opposition, thus indicating that it has a better than even chance of being the victor in a war and acquiring power from its opponent(s), it then will decide to join a conflict or to escalate it, depending on the particular point of the simulation requiring a decision.

In contrast, the sophisticated style reflects a greater awareness of the costs and benefits that derive from participation in a war. Since we wished to retain some ties to the primitive power seeking decision style so as to facilitate comparisons between the two, we implemented sophisticated power seeking as a two-step decision-making process. In the first step a sophisticated power seeker calculates the probability of victory for its side in a potential war. If it estimates that the probability is greater than 0.5, it moves to the second step of the process: but if the estimated probability is 0.5 or less, it neither joins nor escalates the conflict within which it is embedded. In the second step of the process, it calculates the expected power gains that would derive from winning the war and compares this to the gain that would accrue if it were to stay out of the war and acquire power simply through internal growth. If the
gain from fighting a war is greater than that from non-participation, the state escalates the conflict; otherwise it does not.

As a run of the simulation is initialized, a parameter for the proportion of sophisticated power seekers in the system is input. On the basis of this parameter, the two decision-making styles are then randomly assigned to the initial 98 states in the system. Note that this fixes the decision-making style for the state until such time, if it is endowed with the ability to do so, that it makes a higher level choice to alter its mode of decision making (see below).

In the normal choice circumstances within the execution of the model—e.g., conflict initiation, joining alliances, conflict escalation—the decision-making style of the state is examined and the appropriate type of calculation is made. In detail, the calculations are as follows. The power estimation ability of the state plays a role. Power estimates are generated by multiplying the actual power value by a factor representing a combination of the power estimation ability of the state and a random component. This factor is obtained by drawing a normally distributed random number from a distribution with a mean equal to the state's power estimation ability, and a standard deviation equal to the parameter specified for the run.

The primitive power seeker makes power estimates for each side and compares the two. If it estimates its side's power as larger than the opponent, it opts for the escalatory choice, otherwise it does not. The sophisticated power seeker uses the two power estimates as input into a logistical function to calculate the probability of victory. This is the same function that is used in the simulation to determine the outcome of a war. Note that a probability of victory of 0.5 is equivalent to the two sides being equal in power; thus, using this threshold is the same as asking whether the state is on the more powerful side. If the probability based on the power estimate is greater than 0.5, then the sophisticated power seeker assesses the expected gains from winning the war. Using the power estimates for both sides, the state estimates the war fighting cost, the amount of power it will gain from the reparations paid by the losers, and the power it will gain from the territorial acquisitions it can expect to receive from the coalition leader of the losing side. This total is compared to the amount of power it would gain from staying out of the conflict and increasing its power at the internal growth rate. If the gain from fighting is greater than that from internal growth, the state engages in escalatory behavior. Otherwise, it does not.

**ADAPTATION IN DECISION-MAKING STYLES**

Adaptation, as the term is used here, conveys the notion that states will observe their environment, make assessments of the relative success of alternative decision-making styles, and attempt to align their own styles with that which has recently proven most successful.

In observing the environment each state categorizes the members of the system into two groupings, those employing the decision-making style that it practices and those employing another. The state then generates two estimates of the power of every state in each grouping, one for the present iteration and another from \( t \) iterations ago (\( t \) is a model parameter), and calculates the change in the total power that has been experienced by each group. Note that this estimation and calculation process occurs only periodically (every \( t \) iterations). Each group's total change is then divided by the number of states that belonged to the group \( t \) iterations ago, yielding the average power change for each group. The number of states in each group can
change through time. This change, of course, derives from the occurrence of war and the destruction of states involved in war. In calculating the total change for a group, states that have been destroyed are credited with having zero power in the present iteration.

The relative success of the two groupings is then assessed by the state. Based on its estimates, the more successful decision-making style is designated as that practised by the group that has experienced the largest perceived average power change. At this point, the state decides whether it should retain its decision style or alter it. Once that decision is made, its implementation is contingent on two factors: (1) its ability to engage in adaptive behavior (based upon its organizational flexibility, which is embodied in a constant probability with which it was imbued at the outset of the simulation run), and (2) a random component whereby the model stochastically generates, from a uniform distribution of numbers ranging between 0.0 and 1.0, a value. If the state's organizational flexibility parameter is greater than the stochastically generated value, the state is able to affect a switch in its decision-making style should its calculations have indicated that its present mode is inferior. No change will occur if the state is using "best practice" or if, when not doing so, its flexibility is insufficient to affect the transition.

Experimental Analysis

**DESIGN**

In order to assess the implications of adaptation for state survival and system endurance we have laid out an experimental design in which we match the initial conditions of pairs of runs. The only difference between each pair is that states have an ability to adapt their decision-making style in one of the runs, but not in the other. By observing the differences between the runs, we can determine if the presence of adaptation has an impact on the survival of individual states, and if it has an impact on the final disposition of the system. The overall design involves varying a set of background conditions, the initial proportion of states using each decision-making style, and (for the adaptation runs) the frequency with which adaptation may occur.

The specific design was as follows. First, a set of five initial conditions was varied. Each of these conditions was assigned one of two different values. These conditions, and the specific values used, were drawn from our previous efforts (Cusack and Zimmer, 1989; Cusack and Stoll, 1988). A brief description of each of these conditions follows.

1. **Distribution of Power:** Here the parameter controlling the dispersion around the average power holding of the states in the initial system is controlled. Specifically, the standard deviation of the initial distribution, which is normal, is experimentally set so that with the mean value of 100, the "narrow" case has a standard deviation of 10, while taking a value of 25 in the "broad" case.

2. **Error:** In every instance where the modeled states assess others' or their own power, an opportunity arises for error to invade the process. The error is symmetric in that it is normally distributed around a mean of 0.0 with negative (underestimation) and positive (overestimation) values possible. The error itself is created by a random number generator, which produces normally distributed values having a standard deviation of 10 percent (low error) or 50 percent (high error).

3. **War Cost:** Both sides in a war are represented as suffering proportionally equal
losses due solely to their participation in the war. The relative power of both sides acts to determine the scope of these losses with relatively balanced power ratios producing greater losses all around. The maximum loss that can be suffered is specified with the WarCostMax parameter and the experimental values employed in the study are 10 and 20 percent.

4. Reparations: The relative size of the indemnity that each member of a coalition must pay as a result of defeat in war can be varied to reflect the relative absence of restraint on the part of victors. In the more restrained version this parameter is set at 10 percent. In the less restrained version it is increased to 20 percent.

5. Likelihood of Victory: The likelihood of victory function can be specified so as to heighten or lessen the degree to which war's outcome is more or less sensitive to marginal changes in the relative power ratio of the opposing sides. The two values used for this study were 1.0 and 3.0.

Thus, there are a total of 32 different combinations of possible background conditions. We also varied the initial distribution of decision-making styles among the states. Three initial distributions were used: 25 percent sophisticated power seekers, 50 percent sophisticated power seekers, and 75 percent sophisticated power seekers. When taken in combination with the possible background considerations, this produced 96 (32 × 3) sets of initial values.

The third set of varying conditions involved the adaptation frequency (i.e., the number of iterations between the evaluation of the relative success of the two decision-making styles). In one set of runs, the evaluation was conducted every 20 iterations, and in the other set, every 40 iterations. For all runs in which adaptation was allowed, one-third of the states had an adaptation probability of 0.0, one-third had an adaptation probability of .5, and one-third had an adaptation probability of 1.0.

In order to have a run with each of the 96 possible combinations of background condition and initial decision-making style, and to vary the adaptation frequency, a total of 192 (96 × 2) runs were necessary. Each of these adaptation runs was preceded by a run with the same background conditions and initial decision-making style (i.e., a total of 192 no adaptation runs—two runs for each combination of background condition and initial decision making style), but with no adaptation of decision-making style allowed.

The initial power value, power estimation value, and decision-making style randomly generated for each state in a no adaptation run were used as the initial values for that state in the corresponding adaptation run. For example, if state 4 had an initial power value of 105, a power estimation value of 1.05, and used primitive power seeking in a no adaptation run, state 4 would have these same initial values in the matching adaptation run. This matching actually occurs in two pairs of runs: one pair in which the adaptation frequency was 20 iterations, and the other in which the adaptation frequency was 40 iterations. By matching the individual state values, there could be only two sources of variation between the no adaptation and adaptation runs of a pair: the random variation introduced by the stochastic elements in the model, and the ability of individual states to adapt. This sort of matching makes it a simple matter to compare results from a pair of runs at the system level, and even to talk meaningfully about the state-level effects of adaptation.
ANALYSIS

System-Level Findings

In the adaptation runs, the average number of states remaining at the conclusion of a run (out of the initial 98) was 10.5; the average number in the corresponding no adaptation run was slightly smaller (9.3), but the difference was not statistically significant using a paired comparison t-test (t-value = 1.30; p = .2). The final proportion of sophisticated power seekers in each type of run was also almost identical (a little over 70 percent for both types of runs).

To measure the final power distribution in the system, a measure first used by Singer, Bremer, and Stuckey (1972) called CON was employed. In the CON measure, the observed standard deviation of power scores is divided by the maximum possible standard deviation. This maximum would occur if one state possessed all the power in the group. CON ranges from 0 to 1, with the minimum value occurring when power is divided evenly across all the states, and the maximum occurring when one state has all the power. Power is less concentrated in the adaptation runs than in the no adaptation runs. The average CON value in an adaptation run is 0.43, and CON averages 0.50 in no adaptation runs. A paired comparison t-test indicates that this is a statistically significant difference (t-value -3.38; p < 0.001).

The most interesting finding at the system level concerns the duration of the system. In those runs with adaptation allowed, the average duration of the system was 383 iterations. But in the runs with no adaptation, the average duration of the system was 411 iterations. The paired comparison t-value is -2.98, with a probability < .004. This indicates that a world in which adaptation of decision making is allowed is likely to evolve sooner to empire than one in which no adaptation is permitted.

Why should this happen? When states can adapt their decision-making style, they of course will pick the one that has been most successful recently (i.e., the one which has produced the larger power gain recently). But in the world of this simulation, success means winning wars. So when states adapt, they adapt to a decision-making style that is more likely to win wars. But wars also destroy states. When most of the states in the system have a decision-making style that wins them wars, this should produce a higher attrition rate among the states that have not adapted. In the long run, we expect that a high degree of adaptability will aid the survival of individual states, but by producing a more deadly world, it will also decrease the size of the system at a faster rate, and therefore shorten the time until the system is dominated by a single state.

To complete the system-level analysis, we examine a multivariate model used to predict the endurance of the system. We conduct separate analyses for the no adaptation and adaptation runs. For the former, we predict the number of iterations the system survives from the background variables, and the initial percentage of sophisticated decision makers. We use the same variables for the analysis of the adaptation runs, and also include a variable to measure the adaptation frequency in the runs. The results of these analyses are displayed in Tables 1 and 2.

A comparison of Tables 1 and 2 shows that most of the predictor variables have similar effects on the duration of the system. We will concentrate on the differences between the two tables. The maximum war reparations variable has a far more negative effect on the duration of the adaptation runs than on the no adaptation runs (a value of -1000 versus a value of -255). Large war reparations result in a greater chance of destruction of the losers in a war in adaptation runs than in runs...
Table 1. No Adaptation Runs: System Endurance. (Dependent Variable is Duration of System).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>194.69</td>
<td>4.91</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Standard Deviation of Initial Power</td>
<td>0.56</td>
<td>0.64</td>
<td>.52</td>
</tr>
<tr>
<td>Standard Deviation of Power Estimation</td>
<td>-65.47</td>
<td>-2.00</td>
<td>.05</td>
</tr>
<tr>
<td>Sigma Value for Likelihood of Victory</td>
<td>36.40</td>
<td>5.56</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Maximum War Participation Cost</td>
<td>764.17</td>
<td>5.84</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Maximum War Reparations</td>
<td>-255.21</td>
<td>-1.95</td>
<td>.05</td>
</tr>
<tr>
<td>Initial Percentage of Sophisticated</td>
<td>154.19</td>
<td>4.81</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Power Seekers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N = 192. Adjusted R-square = 0.32

Table 2. Adaptation Runs: System Endurance. (Dependent Variable is Duration of System).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>328.49</td>
<td>9.10</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Standard Deviation of Initial Power</td>
<td>-1.07</td>
<td>-1.51</td>
<td>.13</td>
</tr>
<tr>
<td>Standard Deviation of Power Estimation</td>
<td>-64.40</td>
<td>-2.41</td>
<td>.02</td>
</tr>
<tr>
<td>Sigma Value for Likelihood of Victory</td>
<td>29.82</td>
<td>5.58</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Maximum War Participation Cost</td>
<td>897.40</td>
<td>8.40</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Maximum War Reparations</td>
<td>-1000.10</td>
<td>-9.36</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Initial Percentage of Sophisticated</td>
<td>35.84</td>
<td>1.37</td>
<td>.17</td>
</tr>
<tr>
<td>Power Seekers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptation Frequency</td>
<td>1.01</td>
<td>1.89</td>
<td>.06</td>
</tr>
</tbody>
</table>

N = 192. Adjusted R-square = 0.51

With no adaptation. This is consistent with our argument that a world of adaptation is one with a higher attrition of states.

Another difference between the two analyses is the weaker effect of the initial proportion of sophisticated power seekers on the duration of the system. All else being equal, sophisticated power seekers will engage in fewer wars than will primitive power seekers. Thus, a system with a large proportion of sophisticated power seekers can be expected to experience less war, and therefore less attrition of states, than a system with a small proportion of sophisticated power seekers. This is the reason for the strong positive effect of the proportion in the runs with no adaptation. But in the adaptation runs, the proportion of sophisticated power seekers may decrease greatly after the success of decision-making styles is evaluated; it may also increase greatly as well. These large swings weaken the relationship between the initial proportion of sophisticated power seekers and the duration of the system.

The final difference in the results of Tables 1 and 2 is the impact of adaptation
frequency (which of course has a constant value of 0 in the no adaptation runs). Although it does not have a strong effect on the duration of the adaptation systems, the apparent effect is in the positive direction. This indicates that the less frequent the adaptation (i.e., the longer the duration of iterations between evaluation of decision-making styles), the longer the duration of the system (since the values for the adaptation frequency variables are 20 and 40, this means there is an average 20-iteration increase in duration in the runs with the larger adaptation frequency). Since the effect is not strong, we need not dwell on it, but we should note that this coefficient is consistent with our explanation for the impact of adaptation on the duration of the system.

Finally, we note that the fit of the adaptation runs is a good deal higher than that of the no adaptation runs (an adjusted R-square of 0.51 versus an adjusted R-square of 0.32). The better fit is due primarily to the larger impact of the maximum war reparations variable. Taken all together, we believe the results, while not overwhelming, clearly demonstrate that giving states the ability to adapt their decision-making style has a negative effect on the duration of a multistate system.

State-Level Findings

At the state level, we also offer a pair of analyses of the length of time a state survives; one for states in runs with no adaptation, and the other for states in runs with adaptation. As before, we include the values of the background conditions in the analysis. As well, we include three variables for the initial characteristics of the individual state: its initial power, its power estimation ability, and its initial decision-making style. Finally, for the adaptation runs, we also include the background condition of adaptation frequency.

One additional variable is included in the analysis of the adaptation runs for the individual state: the number of decision style switches a state makes divided by the

Table 3. No Adaptation Runs: State Endurance. (Dependent Variable is Number of Iterations a State Survives).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.24</td>
<td>0.15</td>
<td>.88</td>
</tr>
<tr>
<td>Standard Deviation of Initial Power</td>
<td>-0.36</td>
<td>-2.74</td>
<td>.006</td>
</tr>
<tr>
<td>Distribution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Deviation of Power Estimation</td>
<td>-16.30</td>
<td>-3.31</td>
<td>.001</td>
</tr>
<tr>
<td>Distribution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma Value for Likelihood of Victory Function</td>
<td>17.45</td>
<td>17.73</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Maximum War Participation Cost</td>
<td>606.64</td>
<td>30.80</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Maximum War Reparations</td>
<td>-621.03</td>
<td>-31.55</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Initial Percentage of Sophisticated Power Seekers</td>
<td>116.79</td>
<td>22.12</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Initial Power of State</td>
<td>0.65</td>
<td>12.55</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Power Estimation Ability of State</td>
<td>5.22</td>
<td>1.82</td>
<td>.07</td>
</tr>
<tr>
<td>State Begins as a Sophisticated Power Seeker</td>
<td>35.38</td>
<td>16.50</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

N = 18804. Adjusted R-square = 0.16
Table 4. Adaptation Runs: State Endurance. (Dependent Variable is Number of Iterations a State Survives).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>34.59</td>
<td>3.95</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Standard Deviation of Initial Power Distribution</td>
<td>-0.60</td>
<td>-4.63</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Standard Deviation of Power Estimation Distribution</td>
<td>-2.22</td>
<td>-0.46</td>
<td>.65</td>
</tr>
<tr>
<td>Sigma Value for Likelihood of Victory Function</td>
<td>15.35</td>
<td>15.94</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Maximum War Participation Cost</td>
<td>723.62</td>
<td>37.56</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Maximum War Reparations</td>
<td>-793.06</td>
<td>-41.11</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Initial Percentage of Sophisticated Power Seekers</td>
<td>36.81</td>
<td>7.12</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Adaptation Frequency</td>
<td>0.77</td>
<td>8.00</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Initial Power of State</td>
<td>0.64</td>
<td>12.68</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Power Estimation Ability of State</td>
<td>3.53</td>
<td>1.26</td>
<td>.21</td>
</tr>
<tr>
<td>State Begins as a Sophisticated Power Seeker</td>
<td>16.05</td>
<td>7.61</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Proportion of Opportunities to Switch Decision Making Style</td>
<td>55.58</td>
<td>16.55</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

N = 18804. Adjusted R-square = 0.18

number of opportunities the state has to make such switches. This proportion is an indication of how much adaptation a state actually undertakes during a run. The results of the two analyses are shown in Tables 3 and 4.

As with the system-level analysis, we will concentrate on the differences between the finding for the no adaptation and adaptation runs. But before moving to this discussion, we want to take note of one similarity between the two tables: the low fits of the equations. This is consistent with one of our earlier studies (Stoll, 1986). We believe that the evolving dynamics of the system have a good deal to do with the life and death of particular states, and none of the measures employed in this study effectively reveal these dynamics.

The first difference in the two analyses is the smaller negative impact of the standard deviation of power estimation ability on the survival of states in the adaptation runs; in fact, it has almost no effect in these runs. In general, a larger standard deviation means that states will make greater mistakes in their estimation, and pay the price with a disastrous war involvement. But if states are able to adapt their decision-making style to change to the style which has produced more success, this may to a certain extent cancel out the misestimation effect.

The second difference is that the initial percentage of sophisticated power seekers has a smaller impact on the survival of states in the adaptation runs. We believe that this is for reasons which parallel those discussed in the system level results. The greater the percentage of sophisticated power seekers, the less the rate of attrition of states. But in the adaptation runs, the proportion of sophisticated power seekers at any time may bear little relation to the initial proportion, since large numbers of states may move back and forth between styles. Similarly, a state's initial decision-making style may change many times during a run, so it is not surprising that this
variable has a smaller impact on a state's survival than in the no adaptation runs.

Finally, the variable in the adaptation runs which taps a state's actual adaptability during a run has the expected effect. It is strongly positive. Adapting the decision-making style to the particular circumstances of the time does help a state to survive.

Conclusions

This is one of a series of papers in which we are attempting to explore the implications of a variety of conditions in a simulated world. This simulation of an anarchic multistate simulated world was built to contain many of the essential features described in much of the traditional Realpolitik/Balance of Power literature. We believe that this research tool allows us to observe the workings and long-term evolution of a multistate system and its individual members, a task that might otherwise be extremely difficult.

In this paper, we have examined what happens when states are given the ability to change their decision-making style if recent history gives evidence that their current style has not been successful. Although the impact of adaptation is not overwhelming, it would appear to have some interesting effects at both the system and state level. For the individual states, adaptability is positively related to state survival. But a multistate system in which adaptation is possible has a shorter life span than an identical system without adaptation. The divergence in effects occurs because the impact of adaptation on a state is to make it more successful in gaining power. However, in this simulated world, power is gained primarily through winning wars. But the more thorough the victory for one state, the more thorough the defeat for another state. Thus, a world in which many states can adapt is a world in which the attrition of states is high. This results in a shorter life for the system, even if it aids the survival of some of the states which make up the system.

Notes

1. We have provided a lengthy discussion of the application of the selection principle in both economics and in Realist thought in an earlier paper (Cusack and Stoll, 1988).
2. The results of an earlier simulation experiment we conducted suggest that rational decision processes in an anarchistic multistate system may prove counterproductive for those that practice it, although the system level implications appear to be favorable with respect to preserving pluralism (Cusack and Stoll, 1988). These actor-level results are also in accordance with Winter's (1964) study of "Economic 'Natural Selection' and the Theory of the Firm."
3. The reason for this is as follows. If a state calculates it will be on the larger side in the war, it will always get involved if it is a primitive power seeker. But if it is a sophisticated power seeker, it may decide that the costs of the war outweigh the benefits, and not get involved.
4. At first glance, it would seem more straightforward to use either the probability of adaptation or the actual number of decision-making style switches to measure the actual adaptability of a state. But the probability of adaptation is different from the actual number of switches made by a state; for example, for all states with an adaptation probability of .5, the range of actual number of switches is 0 to 11. And the actual number of switches should increase as the state survives through a number of iterations, even if the switches are unrelated to the chances of survival. For example, assume that a state makes 2 switches in the first 100 iterations. If that state survives an additional 100 iterations, the total number of switches it makes cannot go down, and there is a good chance it will rise. Thus, when using this measure we face the possibility that the correlation between it and the number
of iterations survived may well be spurious. In fact, if the total number of switches is included instead of the proportion of opportunities that a state actually switches styles, the total number has a far more significant effect (a t-value of 77.6 instead of 16.6). However, we are reluctant to place a substantive interpretation on this variable.

5. We note parenthetically that finding such measures which can be created from the standard output of the simulation, and which are not intertwined with the phenomena we seek to explain, is not an easy task.

References


Biographical Notes

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