PREFERENCE CYCLING IN INTERNATIONAL INSTITUTIONS:
AN AGENT-BASED MODEL OF TWO-LEVEL GAMES

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When negotiating international agreements, rarely do statesmen have a simple up-or-down decision. Rather, the sheer number of options may complicate negotiators' efforts to reach an agreement. In the months before the Iraq War of 2003, for example, the United States and its traditional allies did not simply debate whether or not to go to war. Rather, U.S. policy makers faced several options: they could seek the imprimatur of the UN Security Council; they could solicit multilateral support through NATO, as they did in the war in Afghanistan; they could pursue a unilateral war; they could wait and revisit multilateral options; or they could do nothing. Likewise U.S. allies had multiple options in response to American proposals: support the United States' position in the Security Council; support the United States within the framework of NATO; support the United States bilaterally, as the United Kingdom did; encourage the United States to be patient; or to express opposition to the U.S. war. Clearly the United States and other states both had differing preferences about how to proceed toward Iraq, and faced different gains and losses from the ultimate policy choice. In addition to the cooperation problem posed by differing preferences and the unequal distribution of gains, however, the U.S. and other states faced an informational problem as well. That is, states needed to learn about each other's preference rankings from among multiple choices. Complicating this learning was the fact that in France, Germany and elsewhere, concerned and motivated citizens rapidly reconsidered and reprioritized their own goals as events unfolded in 2002 and 2003. It was unclear to American leaders, as a consequence, not only what the policy preferences of other negotiators were, but also which options might win sufficient popular support among the electorates in important states.

This process of learning and communication may have profound consequences for the prospects for cooperation, independent of the problems of cheating and the distribution of gains. As Putnam (1988) and Fearon (1994) have shown, domestic constraints on negotiators can

delimit the range of possible choices for negotiations in international organizations. For this reason skillful negotiators may deliberately educate other statesmen about their domestic constraints, in order to gain a greater share of the spoils of an agreement. Yet negotiators also need to sort through each other's preferences from among more than two options. Such *n*-choice problems can create problems for interest aggregation, as classic social choice theorists recognized. There is a rich literature in the rational choice tradition of social choice theory that addresses different pathologies (Black 1948, Arrow 1963 [1951], Duverger 1972, Riker 1976). Of greatest interest to this paper is the possibility of preference cycles, first recognized by the Marquis de Condorcet. In brief, societies may have intransitive preferences in *n*-choice decisions even if individual preferences are perfectly ordered and transitive. When statesmen must decide from three or more choices, their efforts may produce preference cycles that frustrate international agreements.

It is surprising that the study of international institutions has yet to adopt these insights of social choice theory. After all, like their domestic counterparts international institutions are congeries of decision-making rules, principles, norms and procedures (Krasner 1982). In principle these institutions will suffer from the same dilemmas of social choice in the *n*-choice problem as state-level electoral institutions will. In this paper, I simulate a three-choice coordination problem in international negotiations. The three-choice coordination problem is interesting because it has no unique equilibrium solution. Hence, in the absence of an equilibrium solution, such social choice problems may present interesting dynamics. Of theoretic interest, then, is the process through which negotiators solve the coordination problem. It is the path history of negotiation that is as interesting as is the outcome of the coordination game. Game theory is of little help in understanding these path histories, while empirical analysis may face confounded by nonlinearities that both violate classical statistical assumptions and obscure underlying causal mechanisms. For these reasons, I develop an agent-based model, a method of

simulation based on the insights of complex systems theory. The model explores the conditions under which the three-choice problem leads to coordinated behavior, and conversely the factors that may explain failure to coordinate through international negotiations. The simulation uses Putnam's well-known two-level games model (1988) to illustrate the complexities of international negotiations in which states have multifaceted and changing preferences—actors at both the state and systemic level may have preferences, and their choices may evolve through a range of policy options. While the agent-based model is somewhat simplistic, I seek to illustrate how it produces some insights into international negotiations that are non-obvious and that shed light on some extant theoretical debates. These include questions about the optimum number of negotiating partners (Olson 1965, Kahler 1992); the role of transnational factors in coordinating state behavior (Keck and Sikkink 1998); and the consequences of reverberation for the prospects of international agreement (Putnam 1988; Odell 1993). The paper also suggests some extensions of the model that may offer even richer insights into the complexities of international negotiations in an interdependent world.

Social Preferences as a Complex Adaptive System

The aggregation of preferences in international organizations exhibits the properties of a complex adaptive system, or CAS. Complex systems theory suggests that CAS are ubiquitous in the natural and social worlds, and that all CAS share some common properties. First, CAS consist of multiple agents who act autonomously, free from the control or influence of central authority. The analogy to the notion of anarchy in international relations is readily apparent—irrespective of whether or not one adheres to the neorealist or neoliberal institutionalist conception of anarchy (Baldwin 1993).[1] Because of this autonomy of agents, CAS exhibit

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[1] In fact, one can treat this theoretical disagreement as a variable property of a complex adaptive system. As several scholars have noted, states' sensitivity to relative gains (and hence the prospects for

massive parallelism and multiple levels of organization, with actors at one level aggregating into

actors at another level (Waldrop 1992). This focus on agents at multiple levels reflects the

growing richness of levels of analysis in international relations. Second, the actors in CAS follow

local and often simple decision rules, and incorporate their local knowledge about the system into

their decision routines. Actors in a CAS, like states in the international system, may have

imperfect and incomplete information, but nevertheless they learn and adapt as the system

evolves over time. Through the years much of the debate in international relations theory

concerns how to characterize these rules. Do states behave like atomistic rational utility

maximizers, as structural theories assert? The exigencies of survival in an anarchic system may

force states to maximize their gains. Alternatively problems of collaboration and coordination

may encourage states to create institutions to solve collective action problems, while the shadow

of the future may make cooperation easier to achieve. Despite their considerable differences,

structural theories like neorealism and neoliberal institutionalism are united in their conception of

states as being concerned with maximizing their gains, whether absolutely or relative to other

states. In this respect IR theories in the structural tradition argue that states follow precisely the

simple decision rules that typify agents in a CAS, even if scholars disagree over precisely which

rules may best help us understand the complexities we observe.

The learning behavior of agents produces the third property of complex adaptive systems.

The systems themselves grow, change, evolve and adapt as agents in the system learn and

incorporate new information into their routines. These dynamics are more than simply the

aggregation of local interactions alone, furthermore. As Holland (1992: 17-30) has illustrated,

agents who follow even conditioned and simple decision rules can produce systemic behavior that

is complex and not repeatable. This evolutionary property of CAS thus emphasizes the

importance of path dependence and history in understanding a system: it calls our attention to

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cooperation) vary across issue areas. This variation in sensitivity itself is an important emergent property
of a complex adaptive system of nation-states.

dynamics rather and away from our traditional focus on equilibria. Much recent theory in IR is concerned with whether and how states learn, from the neofunctionalism of Ernst B. Haas (1964, 1990) to ideas about socialization of states and "world models" (Meyer et. al. 1997). Complex systems theory thus is consistent with IR theories that emphasize learning and change as a corrective for the static bias in structural theories. (Ruggie 1986)

As institutions for the aggregation of states' preferences into social choices, one can argue international organizations exhibit the properties of a complex adaptive system. Sovereign states pursue internal (local) decision rules, even if the source of state preferences is a point of theoretical debate. In the anarchic international system, states' decisions are autonomous even if their payoffs may be interdependent. States learn and adapt in ways that change both the structure of interaction and their own expectations. States and non-state actors produce structural phenomena that are greater than the sum of their localized interactions, from conflict to the very anarchic structure of the international system (Wendt 1992). A complex systems theorist who looks at IR theory no doubt will recognize much.

The Methodology of Simulation

Traditionally researchers have studied social choice problems using the formal methods of game theory. Recently, however, a number of researchers have used the method of agent-based modeling to simulate voting institutions (see Wilensky 1998, Kottanau and Pahl-Wostl 2004; Reed 2004; Earnest forthcoming). In brief, this method uses quasi-parallel processing to simulate a complex adaptive system.[2] The modeler populates a virtual world of actors, assigns them properties and decision-making rules, defines an environment, and explores systems-level

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[2] Parallel processing technically refers to a simulation that uses a unique microprocessor for each actor in a simulation. With the speed of modern computing, even an inexpensive personal computer has the speed to conduct "quasi" parallel processing, in which a single microprocessor enacts the decision rules for each agent in the simulation before the model takes the next "step" in time. While quasi-parallel processing may create scheduling issues, for the purposes of this paper I assume these problems are trivial.

changes in the model. Each actor in such a computer-based model may enact the same decision rule, but do so on the basis of their unique knowledge, learning and local circumstances. These multiple decisions produce "emergent" behavior—that is, micro-level interactions produce macro-level outcomes of interest. These systemic phenomena typically are the behaviors that most interest researchers. Agent-based models attempt to "grow" these phenomena from simple, local decision algorithms (Epstein and Axtell 1996; Axelrod 1997).

Agent-based modeling offers a number of advantages over both statistical and formal methods (though these models have their own problems; see Pepinsky 2005, Earnest and Rosenau 2006). First, agent-based modeling focuses on nonlinear and interactive dynamics rather than on equilibrium solutions. As Pepinsky (2005, p. 370-71) has suggested, nonlinear systems often exhibit the property of chaos. Parameters in chaotic systems apparently vary randomly, so researchers cannot model them mathematically even though their dynamics may arise from deterministic rules (Elliott and Kiel 1997). For this reason researchers cannot characterize these systems using structural equations. Simulations offer an alternative method of investigating the emergence of such dynamics. Thus the method of agent-based modeling combines the deductive, rule-based methods of formal theory with the inductive appeal of empirical methods (Axelrod 1997).

This inductive aspect of agent-based modeling suggests a second reason for using the method. Because the researcher constructs such model in a computer, he or she can quickly and easily explore how alternative specifications of a model may affect the outcome of interest. This exploration of counterfactuals allows researcher to produce alternative "histories" of a nonlinear system that empirical methods do not permit (Fearon 1991, Pepinsky 2005). Third, as Simon and Starr (1996) note, agent-based models permit the researcher to probe for internal inconsistencies in a model. By exploring the parameter space, either through the iterative combination of parameter values or through artificially intelligent algorithms, a researcher may uncover

particular values of factors that give rise to phenomena of interest. This can allow researchers to gain theoretic insights, but also to uncover hidden assumptions and causal factors that are not plausible. For example, Miller (1998) used a genetic algorithm to explore the parameter space of a well-known computer simulation of resource depletion and environmental degradation (Meadows et. al. 1974). Miller found that the simulation's dynamics reflected in large part the interaction of two particular factors that, with changed assumptions, substantially altered the model's theoretical implications.

Agent-based models offer the researcher a fourth advantage. They allow a researcher to uncover non-obvious implications of nonlinear systems. By their very nature, nonlinear complex systems produce surprising outcomes: minor micro-level perturbations may produce considerable macro-level changes—the well-known "butterfly effect" first discussed by Lorenz (1963). Alternatively large macro-level fluctuations may dampen out over time. One cannot easily study these nonlinear dynamics empirically, since statistical techniques require either knowledge of the data generation process (in which case statistics is superfluous) or strong assumptions about the structural equations (which may limit the generality of findings). Of course, formal theory explicitly seeks to uncover such non-obvious implications by proceeding deductively from axiom to outcome. By focusing on equilibria as solutions, however, formal theory may eschew precisely those non-obvious implications that are of most interest to the researcher. Agent-based modeling, by contrast, permits the researcher to induce nonlinearities and to uncover surprising implications of simple decision rules. A classic example is Schelling's segregation game (1978). Though Schelling used pennies and dimes instead of a computer, his technique followed the principles of agent-based modeling and illustrated how even tolerant individuals can produce patterns of stark residential segregation. Miller (1998) shows how researchers can use "genetic algorithms," a type of artificial intelligence, to uncover hidden relationships between parameters

in a nonlinear system. The method of agent-based modeling thus may offer the researcher insights into nonlinear dynamics of a system that existing techniques tend to obscure.

Like all methods, however, agent-based modeling has some problems. Agent-based models treat as unproblematic a variety of ontological concerns that have infused international relations scholarship in recent years (see Pepinsky 2005 and Earnest and Rosenau 2006 for discussions of this point). As Pepinsky (2005, pp. 375-376) further notes, "both the methodology and epistemology of simulation rely on thick ontological and epistemological presuppositions of what agents are relevant, how the environment appears to the agents, and how processes and parameters shape complex systems. . . . unfortunately, these epistemological issues and ontological presumptions are obscured by the methodology." As with formal and statistical techniques, researchers need to avoid reification. One might best think of these models as heuristics.

Preference Aggregation in International Institutions

To construct an agent-based model of decision-making in international organizations, I rely upon the two-level games framework first proposed by Putnam (1988). Every agent-based model makes theoretically informed assumptions about agents; the environment in which agents interact; the rules that govern interactions between agents and between agents and the environment; and the system's behavior over time. As a demonstrated method of empirical analysis, the two-level games framework can help a modeler think explicitly about the nature of agents, the environment, rules of interaction, and outcomes of theoretic interest.

I. The Environment

The "environment" in the model is a social choice problem for nation-states. Following Putnam, I assume that states will negotiate in good faith with each other and will express their

sincere preferences. To simulate the "noise" of international negotiations, the model presents

states with a coordination problem analogous to the "rules of the road": states are indifferent as to

which solution they adopt, but have differing initial preferences among choices (Snidal 1985,

Martin 1992, Wilson and Rhodes 1997, Abbott and Snidal 1998, Mattli and Buthe 2003). In

principle, a two-choice coordination decision should lead easily to a social choice: as states

express and reorder their preferences, the social choice eventually will tip toward one of several

possible equilibria. [3] Once states achieve an equilibrium no one state will have any incentive to

deviate from the solution. Rather than having states negotiate a simple two-choice problem,

however, I opt for a richer three-choice problem. As the Marquis de Condorcet first noted in the

17th century, such three-choice decisions create the possibility for intransitive and cycling social

preferences (see also Radcliffe 1993 and Gaubatz 1995). Unlike the two-choice coordination

problem, the three-choice problem does not necessarily lead to an equilibrium outcome. In fact, a

theoretical interest of the model is to investigate those conditions under which institutions fail to

solve the coordination problem.

Table 1 presents a Condorcet problem with three nominal choices: blue, green and

yellow. A quick glance at the table shows how intransitivities may arise. In any pairwise

comparison of options, any option can defeat the other two. For example, suppose one proposed

a simple decision rule: we would vote on the question of blue versus green first, and then the

winner of that choice versus yellow second. If we followed this choice rule, blue would defeat

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[3] The basic coordination game has two equilibria and hence no unique solution (though it does have a
mixed-strategy equilibrium). The three-choice game is a trivial extension of the two-choice game.
Formally, the two-person three-choice coordination game is:

		Actor B		
		left	*center*	*right*
	up	3, 3	0, 0	0, 0
Actor A	*middle*	0, 0	2, 2	0, 0
	down	0, 0	0, 0	1, 1

Payoffs: (A, B)

			Order of preferences		
Voter	*1*		*2*		*3*
A	Blue	>	Green	>	Yellow
B	Yellow	>	Blue	>	Green
C	Green	>	Yellow	>	Blue

Table 1: A Condorcet decision problem among three nominal alternatives.

green (since A and B both prefer blue to green) but would lose to yellow (since B and C both prefer yellow to blue). Yet if we changed the order of pairwise comparisons, we would get a different collective choice. If we compared yellow to blue first, yellow would win (thanks to B and C) but would lose out when compared to green (thanks to A and C). Hence the social choice has changed with a different decision rule, even though the orders of each individual's preferences have not changed. The Condorcet problem highlights two important concepts: the choice of institutions can never be politically neutral; and societies can cycle through social choices even if individuals maintain constant and ordered preferences.

Martin (1992) shows that coordination problems typically lead states to emphasize norms of multilateralism that help states reduce the costs of achieving an equilibrium outcome. Such coordination problems typically do not require centralized monitoring and enforcement of agreements, since once states have achieved an agreement none has an incentive to defect (see also Krasner 1991). Hence Martin argues that coordination problems do not require formal multilateral organizations. On this basis, the model treats enforcement of agreements as unproblematic. Its focus is not on cheating once states reach an agreement; rather it focuses on the path history of negotiations among states to reach the equilibrium point.

II. Relevant Agents

Borrowing from Putnam, the "agents" of interest in this model are negotiators at Level I (the international level, at which states negotiate agreements) and their domestic constituencies (Level II).   Each agent in the model has *ab initio* preferences for the nominal social choices; these initial preferences satisfy classic assumptions of ordering, transitivity and independence from irrelevant alternatives. The model randomizes agent preferences at the point of generation. Negotiators simply prefer one alternative to the others, e.g. prefers blue to green to yellow. Constituencies by contrast have weighted preferences among the alternatives. This weighting simulates constituencies as amalgamated actors, representing "domestic groups [who] pursue their interests by pressuring the government to adopt their favored policies, and politicians [who] seek power by constructing coalitions among those groups" (Putnam 1988, p. 434). A society will have a distribution of preferences for social choices that rarely if ever will be uniform. The weights always total to one, so that each weight represents the proportion of a constituency that prefers a given choice. In the model's implementation, a constituency will have preferences such as 0.45 green (analogous to 45 percent of the society prefers the green choice), 0.32 blue (32 percent prefers blue), and 0.23 yellow. Admittedly, these modeling choices treat axiomatically many of the domestic political determinants to which Putnam called attention. The goal is, however, to focus on the emergence of interstate cooperation rather than the richness of domestic factors (but see the discussion of extensions of the model below).

The model allows a researcher to vary the number of states in a negotiation. A "mini-lateral" implementation would consist of as few as three negotiators with their three constituencies, while a large multilateral negotiation could consist of as many as 40 negotiators and constituencies.[4] The model thus allows the researcher to investigate whether fewer

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[4] The choice of upper limit to the number of negotiators is an arbitrary one. I chose 40 merely for ease of computation and interpretation. One can quickly rewrite the model, however, to examine a counterfactual

negotiators can reach a social choice more easily than a large number (Olson 1965; Kahler 1992).

The model assumes each negotiator has only one constituency, while likewise each constituency

has only one negotiator.

III. Rules and Parameters

At each step in "time" in the model, the social choice is the plurality winner of the

negotiators' preferences. The model uses four variables. First, negotiators are "sensitive" to the

preferences of other negotiators. The second variable is negotiators' sensitivity to the preferences

of their constituencies. The third and fourth variables relate to the transnational effects among

constituencies. One of these is the "radius" within which transnational effects may occur; this

variable models the idea that not all constituencies have transnational ties with every other

constituency. Finally, the model allows the magnitude of transnational effects to vary. That is to

say, a given constituency may give considerable weight to the preferences of a neighboring

constituency, or may attribute relatively little importance to the preferences of neighbors.

Negotiators change their preferences in two ways. First, in direct negotiation a given

negotiator can change the preferences of another negotiator (labeled X_1 in figure 1). This

simulated negotiation allows for actors at Level I to change each other's minds with some

probability less than one. The model allows the researcher to vary the probability of a given

negotiator persuading another negotiator to simulate either accommodating or obstinate

negotiations. Second, a negotiator will change its preference to accord with their constituency's

preference (X_2). As Odell (1993) has shown, the strength of domestic preferences can affect both

the probability of an agreement and the distribution of gains from any agreement. However, a

constituency will change its negotiator's preference with a probability less than one, to simulate

the ability of negotiators to innovate in Level II negotiations.

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with a large number of negotiators and constituencies, such as negotiations for the reduction of trade
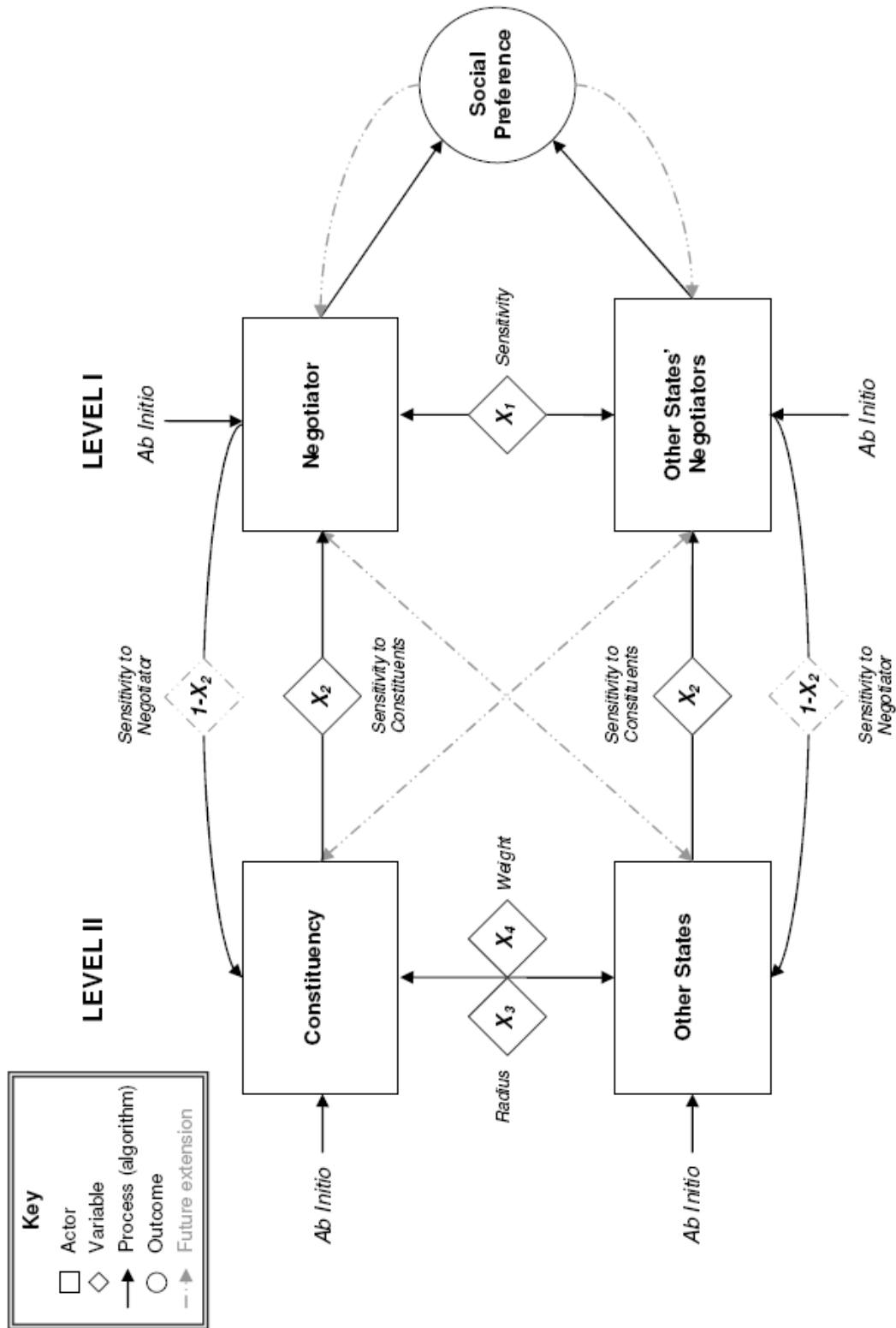barriers in the World Trade Organization.

Figure 1: The model's implementation of a two-level game.

Constituencies change their preferences in two possible ways. First, constituencies respond to the preferences of other states, reflecting transnational interest articulation in world politics. At each step in the model a constituency polls some subset of the other constituencies, and will re-weight and reorder its preferences if its top choice is not the social winner (labeled X_3 in figure 1). The researcher can vary both the magnitude of re-weighting and the number of other constituencies a given constituency will poll (from two neighbors to all other constituency). This reflects the idea that transnational effects are greater between states that are proximate. Thus the modeler can vary both the extent and intensity of transnational effects on preferences in a given state. Constituencies may change preferences in a second way. A negotiator may persuade its constituency to adopt the negotiator's preference. This is analogous to Putnam's observation that a skillful negotiator can expand his or her level II win set (X_4). Figure 1 represents schematically the model's implementation of the two-level game.

IV. Outcomes of Interest

Under what conditions will negotiators reach a consensus? Alternatively, under what conditions will they fail to reach a consensus? Putnam's article and subsequent research (see Evans, Jacobson, and Putnam 1993) offer some answers. A "win set" is the set of all possible agreements among negotiators at level I that constituents at level II would ratify. Several factors may influence the size of a given negotiator's win set. These include preferences and coalitions at the domestic level; institutions and the rules of ratification; and negotiator's strategies. Using this framework, researchers have identified some ironies of international negotiations. Negotiators with accommodating constituencies would more often have to make concessions in international negotiations. Conversely, negotiators with unyielding publics would gain a greater distribution of gains from international negotiations (see Odell 1993 for an interesting study of

these dynamics). Hence level II preferences, articulated by domestic actors through institutions, can shape the prospects of agreement at level I.

The model uses simple algorithms to capture the preferences of domestic actors, the rules of ratification at level II, and the strategies of negotiators. As noted above, constituency preferences simply are weighted values representing the proportion of a society that supports a given choice. The model assumes level II ratification follows simple plurality rules. Negotiator strategies are represented by a probability of influencing their constituency. Using three algorithms, I seek to simulate, first, the emergence of stable level I agreements and, second, the emergence of instability and discord in level I negotiations. To simulate these outcomes, I use Miller's (1998) active nonlinear test or ANT, a genetic algorithm to explore the model's parameter space. My implementation of the active nonlinear test starts with a list of 40 randomly generated parameter sets to run the model. At the end of the first generation of 40 runs, the algorithm undertakes a tournament from among the 40 parameter sets, selecting those that performed best according to a specific fitness criterion. The algorithm also incorporates a genetic crossover routine, in which parameter sets selected by the tournament procedure swap parameter values with sets not selected. This crossover allows for the possibility of fit parameter sets to reproduce even better performing sets. It occurs with a probability that declines over generations, however, to allow the algorithm to converge on a specific parameter set. My implementation of the active nonlinear test conducts the selection tournament and genetic crossover for 40 generations, for a total of 1,600 runs of the model.[5]

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[5] Miller has shown that the active nonlinear test efficiently explores the parameter space of nonlinear models provided the fitness landscape has a single or a few fitness peaks. If not, the test may converge on suboptimal peaks in the fitness landscape, though the genetic crossover routine minimizes this risk.

I use one measure in the ANT to simulate cooperation and discord in two-level games. For each step in the simulation I measure whether or not the level I choice of diplomats concurs with the global distribution of preferences at level II (measured as the weighted support for the winning choice averaged across all constituencies). This is analogous to negotiators concluding agreements that fail to win ratification from their constituencies. When the level I choice is not the level II winner, the model identifies that step as a period of discord. In one test, I used the ANT to maximize the number of steps of discord. In the other the ANT minimizes the discord, analogous to negotiators concluding agreements that most often will win ratification at level II. Figures 2 illustrates how the ANT anneals the model over forty generations, by increasing the
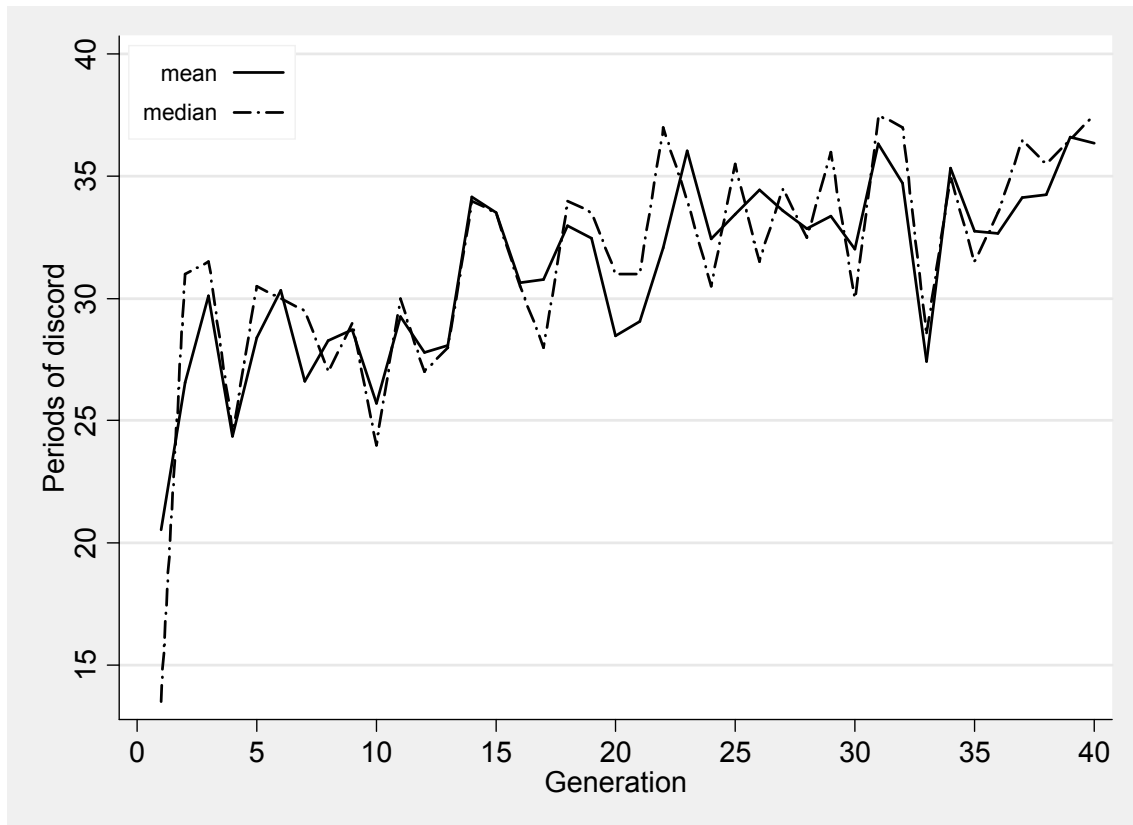

Figure 2: Active nonlinear test's maximization of periods of discord, over 40 generations of the test.
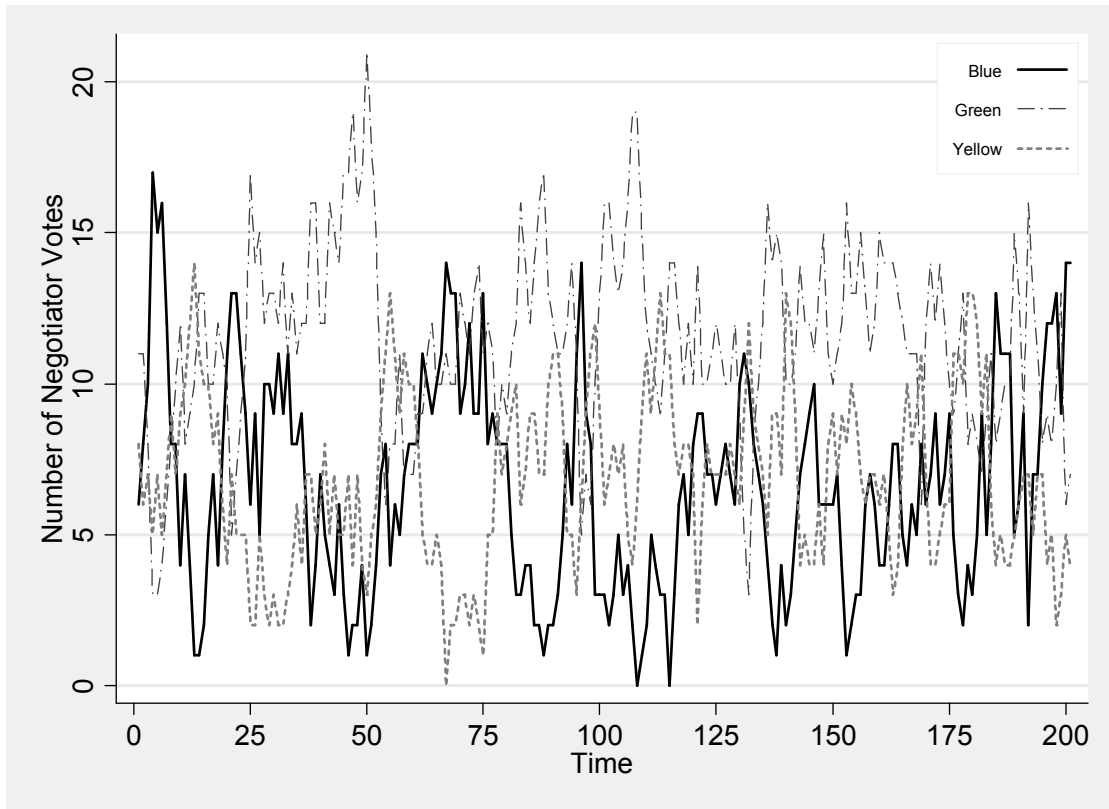
Figure 3: Failure to coordinate the social choice.

average number of time periods of discord in a run of the simulation. Similarly the ANT anneals

the model to maximize the periods of cooperation in the model (i.e. minimizes the number of

periods of discord). For brevity I omit the graph of the model's minimization of discord.

Some Preliminary Findings

Discord occurs when (a) the number of negotiating partners is relatively small; (b) when

transnational networks are sparse; (c) when constituencies are relatively slow to re-weight their

preferences in response to discord; (d) when negotiators have a degree of independence from their

constituencies; and (e) when negotiators are relatively accommodating of other negotiators.

Figure 3 shows a simulation in which negotiators fail to cooperate, cycling among the three

possible choices in the coordination problem. Conversely, negotiations produce coordination at
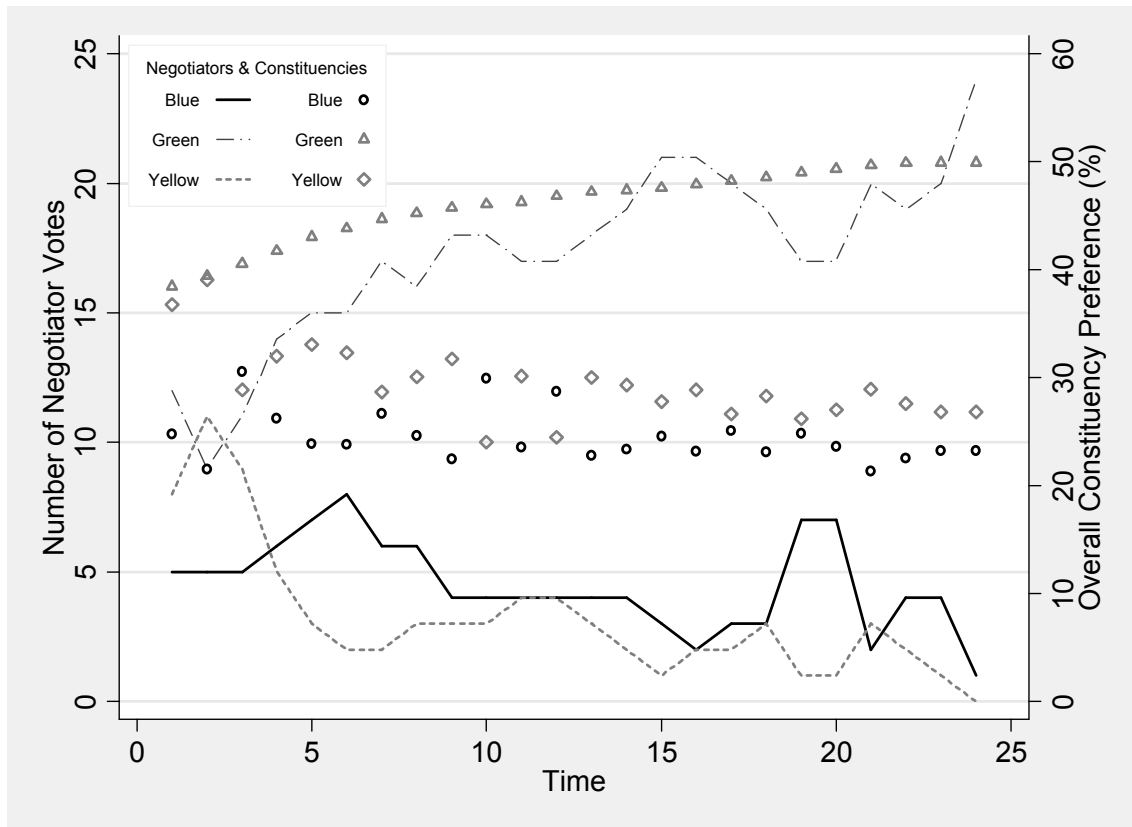
Figure 4: Emergence of a coordinated social choice at *t* = 24.

Level I when (a) the number of negotiating partners is large; (b) transnational networks are dense; (c) constituencies re-weight and reorder their preferences quickly; (d) when negotiators are highly sensitive to constituencies' preferences; and (e) when negotiators are relatively insensitive to other negotiators. Figure 4 exhibits a run of the simulation in which negotiators quickly produce a Level I agreement.

Contrary to expectations, the model finds that a larger number of negotiating partners leads to larger win sets and more agreements. This is contrary both to Olson's (1965) findings about collective action and the literature on international cooperation. Kahler (1992) finds that states have solved large-*n* coordination problems either through "minilateral" arrangements, in which a few great powers agree to a solution that other states then adopt, or through bilateral or regional agreements. In other words, states solve coordination problems by negotiating in smaller

groups. The model presented here illustrates, however, that larger groups offer certain informational advantages in multilateral negotiations. Snidal (1991a, 1991b) for one found that large-*n* negotiations attenuate pressures of relative-gains concerns, making cooperation easier. Independent of concerns for gains, however, this model shows that large-*n* groups may have denser informational networks that allow for the more efficient communication of preferences among states. These informational dynamics in large-*n* negotiations can help states solve coordination problems.

As the model's transnational algorithms suggest, cross-border relationships are another mechanism that facilitates the communications of constituency preferences. This finding is consistent with the interdependence and globalization literature. Keck and Sikkink (1998) find, for example, that dense transnational networks contribute to the convergence of norms supporting regional and international integration and instigate changes in the principles that regulate state behavior.

Putnam focused on the strength of level II preferences to explain not only the probability of an agreement at level I, but also the distribution of gains among states from the agreement. While the simulation presented here does not create a coordination problem with distributional consequences, it nevertheless affirms the importance of the strength of domestic preferences for the prospect of an agreement. As Putnam suggested, negotiators with flexible constituencies achieve stable accords, while inflexible constituencies lead to a greater likelihood of discord. This finding is somewhat qualified, however, both by the absence of distributional concerns in the model's negotiations, and by the model's unrealistic assumption that all constituencies have the same strength of preferences in a given simulation, whether strong or weak. By allowing these assumptions to vary, an extended version of the model might enable a researcher to understand better when the strength of constituency preferences matters.

Finally, the role of negotiators is particularly interesting. The model finds that level I discord occurs when negotiators are relatively free from constituency pressures, and when negotiators are relatively accommodating to other negotiators. These findings are somewhat contrary to the findings of the two-level games literature. Putnam (1988, p. 450) noted that "the larger [the negotiator's] win set, the more easily he can conclude an agreement, but also the weaker his bargaining position vis-à-vis the other negotiator." This simulation suggests a complement to Putnam's reasoning: while negotiators with greater freedom from constituent pressures may be more likely *ceteris paribus* to reach an agreement, such freedom detracts from the informational content of the negotiator's actions. Even a relatively independent negotiator needs to win ratification at the domestic level: by pursuing his or her own preferred objectives, a negotiator fails to communicate to other states the preferences of his or her constituency. This lack of information makes coordination more difficult. This insight suggests one more reason states try to tie the hands of their negotiators. The two-level games literature suggests such constraints help states gain a greater distribution of the gains from an agreement. My model suggests that such constraints help states coordinate in the first place by communication the prospects for domestic ratification, even before negotiators can squabble over the gains.

Likewise, solicitous negotiators may ironically prevent the emergence of coordinated state behavior. As the findings of the active nonlinear test show, negotiators who accommodate other negotiators—particularly when level I bargainers are insensitive to their domestic constituencies—may perpetuate misinformation about the prospects for ratification at level II. That is to say, a solicitous negotiator may pass along information about a level I win set to his or her constituents that a negotiating partner has communicated insincerely. Hence misunderstandings about the coordination win set "reverberate" in the model, tipping the model away from a coordinated solution rather than toward one (see Putnam 1988, pp. 454-55). "Given the pervasive uncertainty that surrounds many international issues," Putnam noted, "messages

from abroad can change minds, move the undecided, and hearten those in the domestic minority."

True—but insincere messages can also harden positions, add to the ranks of the undecided, and

discourage prospective supporters of an agreement. Reverberation can cut both ways, particularly

when negotiators are insensitive to voter preferences and highly sensitive to each other.

Extensions

The highly simplified model presented here offers some interesting insights into the

informational dynamics of two-level games. To create a more realistic simulation, however, the

model should endogenize a number of additional factors.

First, the simulation would benefit from adaptive, intelligent agents. As currently

implemented, the decision algorithms for both constituencies and negotiators are "dumb"

algorithms: constituencies and negotiators have no memory of past outcomes, and do not learn

and adapt in a way that voters and diplomats realistically do. There are a couple of algorithmic

ways to create adaptive, learning agents. One is to give agents a simple memory of past social

choice outcomes that may shape their future preferences and actions. For example, Earnest

(forthcoming) modeled agents who remember whether or not their preferred choice was the social

choice at the last election. When agents are "losers," they pursue different voting strategies. This

is a relatively simple algorithm that nevertheless produces chaotic social choice dynamics. More

ambitiously, one could use genetic algorithms to have agents learn not only about the social

choice but to learn about which voting strategies might "succeed". Though more sophisticated,

the use of genetic algorithms in social simulation is fairly commonplace.

A second extension is to create more realistic algorithms for the ways in which

constituencies articulate their preferences. The current model implements a simple algorithm: a

constituency's "strength" of preferences is simply the probability that another constituency or its

negotiator may cause it to re-weight and reorder its preferences. Yet this probability remains the

same for all agents in the model. As Putnam has shown, however, differences in the strengths of preferences among constituencies can have profound implications not only for the probability of a Level I agreement, but also of the distribution of gains. A more realistic simulation thus should include constituencies with varying strengths of preferences as well as distributional gains from Level I negotiations.

Third, the model's simple coordination game ignores problems of distribution. For one, the model assumes that all three equilibrium offer the same payoffs. The classic coordination game assumes, however, that players prefer one equilibrium to another because that equilibrium has a higher absolute payoff for each player. An extended model could rank the outcomes (e.g. blue win set > green win set > yellow win set > no agreement) and award states for achieving more desirable win sets.   The basic coordination game treats axiomatically, furthermore, distributional games such as the "battle of the sexes," in which states prefer cooperation, but the different equilibria offer a different reward to each state. For example, one state will receive higher payoffs if blue is the win-set equilibrium while another state will receive a greater share of the payoff if green is the social choice. This inclusion of distributional conflicts from social choice problems would make the model applicable to a wider domain of problems of international cooperation.

Finally, the domestic institutions for ratification of a Level I agreement may also affect the prospect for agreement at the international level. The current simulation has a simple level II institution for ratification (plurality) that is common to all constituencies in the model. To test Putnam's argument about the importance of domestic institutions of ratification, the simulation should allow for and test different ratification procedures, such as majority or supermajority requirements. Along with an added distributional component of level I negotiations, this extension will allow the researcher to investigate the consequences of ratification institutions for the prospects of level I cooperation.

Conclusions

This paper illustrates how simulation in the rationalist tradition may generate new insights into the dynamics of international politics. While existing empirical and game theoretic studies have identified factors that contribute to international agreements, the agent-based model here shows how researchers can study the path histories that are important to games with multiple equilibria. The model uses four simple variables: the sensitivity of negotiators to their constituencies, the sensitivity of negotiators to other states' negotiators, the magnitude of transnational effects, and the scope of transnational networks. With these three variables the model illustrates the conditions under which international negotiations may solve coordination problems, and those factors that contribute to preference cycles and ineffective governance. By expanding the model to account for additional factors and by exploring counterfactual assumptions, future modelers can enrich their explanations of different path histories of two-level games. In coordination games with multiple equilibria, game theory is silent on these path histories because it cannot speak to the accidents or idiosyncrasies that may tip a game one way or another. Likewise, empirical methods may have limited utility in studying nonlinear systems which invalidate the classical assumptions of statistical inference. Agent-based modeling thus offers a way forward.

The model also serves a similar purpose to Putnam's original paper on two-level games: it calls attention to the value of using multiple levels of analysis. As Pepinsky (2005, p. 380) notes, "simulations of international phenomena have currently only included states as agents; theory thus pervades the model, and emergence and simulated data are correspondingly tied to theory." This model attempts to move beyond a state-centric ontology by modeling the interactions between state-level preferences and international negotiations. Pepinsky has identified this "variety in ontological assumptions" (p. 385) as an important complement to

existing simulations of international processes (see also pp. 379-384). Likewise, the model simulates the complexity of decision-making in state-level institutions. The model has shown how complex dynamics such as preference cycles can emerge from these decision-making processes. Even the model's simulation of these processes is relatively simplistic, however. Agents in the model do not remember past outcomes, learn or adapt in ways that typify actors in complex adaptive systems. By endowing agents with memory, with adaptive voting strategies such as tactical voting (i.e. voting for a second-preferred option), and with varying preferences, the model may create greater complexity in state-level decision making.

Agent-based modeling is no substitute for empirical studies or for the rational deduction of game theory. Rather, it offers researchers a useful complement that enables rigorous investigation of counterfactuals; a focus on path histories; and the identification of non-obvious implications. As the method develops a richer ontology that focuses on the heterogeneity of actors in world politics, furthermore, the modeling enterprise will rely more than ever on the empirical and rational deductive traditions in international studies. It is these traditions we will call upon to investigate the new insights that we gain from agent-based models.

Works Cited

Abbott, Kenneth W. and Duncan Snidal. 1998. "Why States Act through Formal International Organizations." *Journal of Conflict Resolution* 42, 1 (February): 3-32.

Arrow, Kenneth J. 1963 [1951]. *Social Choice and Individual Values*. New York: Wiley.

Axelrod, Robert. 1997. *The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration*. Princeton: Princeton University Press.

Baldwin, David A., ed. 1993. *Neorealism and Neoliberalism: The Contemporary Debate*. New York: Columbia University Press.

Black, Duncan. 1948. "On the Rationale of Group Decision-making." *Journal of Political Economy* 56: 23-34.

Duverger, Maurice. 1972. *Party Politics and Pressure Groups: A Comparative Introduction.* David Wagoner, trans. New York: Thomas Y. Crowell.

Earnest, David C. and James N. Rosenau. 2006. "Signifying Nothing? What Complex Systems Can and Cannot Tell Us about Global Politics." *Complexity in World Politics: Concepts and Methods of a New Paradigm.* Neil E. Harrison, ed. Albany, NY: SUNY Press.

Earnest, David C. Forthcoming. "Voting Complexity and Electoral Outcomes: An Agent-Based Model of Social Choice Problems." *Complexity and Policy Analysis*. Kurt Richardson, ed. Boston: Institute for the Study of Complexity and Emergence.

Elliott, Euel and L. Douglas Kiel. 1997. "Nonlinear Dynamics, Complexity, and Public Policy." *Chaos, Complexity and Sociology: Myths, Models, and Theories*. Raymond A. Eve, Sara Horsfall, Mary E. Lee, eds. Thousand Oaks, CA: SAGE Publications, 1997: 64-78.

Epstein, Joshua M. and Robert Axtell. 1996. *Growing Artificial Societies: Social Science from the Ground Up*. Washington, DC: Brookings Institution.

Evans, Peter B., Harold K. Jacobson, and Robert D. Putnam, eds. 1993. *Double-Edged Diplomacy: International Bargaining and Domestic Politics*. Berkeley: University of California Press. 233-264.

Fearon, James D. 1991. "Counterfactuals and Hypothesis Testing in Political Science." *World Politics* 43, 2 (January): 169-195.

Fearon, James D. 1994. "Domestic Political Audiences and the Escalation of International Disputes." American Political Science Review 88, 3 (September): 577-592.

Gaubatz, Kurt Taylor. 1995. "Intervention and Intransitivity: Public Opinion, Social Choice, and the Use of Military Force Abroad." *World Politics* 47, 4 (July): 534-554.

Haas, Ernst B. 1964. *Beyond the Nation-State: Functionalism and International Organization*. Stanford, CA: Stanford University Press.

Haas, Ernst B. 1990. *When Knowledge Is Power: Three Models of Change in International Organizations*. Berkeley: University of California Press.

Holland, John H. 1992. "Complex Adaptive Systems." *DAEDALUS* 121, 1 (Winter): 17–30.

Kahler, Miles. 1992. "Multilateralism with Small and Large Numbers." *International Organization* 46, 3 (Summer): 81-708.

Keck, Margaret E. and Kathryn Sikkink. 1998. *Activists Beyond Borders: Advocacy Networks in International Politics*. Ithaca, NY: Cornell University Press.

Kottanau, Johannes and Claudia Pahl-Wostl. 2004. "Simulating political attitudes and voting behavior." *Journal of Artificial Societies and Social Simulations* 7, 4 (October). Online resource available at http://jasss.soc.surrey.ac.uk/7/4/6.html.

Krasner, Stephen D., ed. 1982. *International Regimes*. Ithaca, NY: Cornell University Press.

Krasner, Stephen D. 1991. "Global Communications and National Power: Life on the Pareto Frontier." *World Politics* 43, 3 (April): 336-366.

Lorenz, Edward N. 1963. "Deterministic nonperiodic flow." *Journal of Atmospheric Sciences*. 20: 130-141.

Martin, Lisa L. 1992. "Interests, Power and Multilateralism." *International Organization* 46, 4 (August): 765-792.

Mattli, Walter and Tim Buthe. 2003. "Setting International Standards: Technological Rationality or Primacy of Power?" *World Politics* 56, 1 (October): 1-42.

Meadows, Dennis L., William H. Behrens, Donella H. Meadows, Roger F. Naill, Jorgen Randers, and Erich K. O. Zahn. 1975. *Dynamics of Growth in a Finite World.* Cambridge, MA: Wright-Allen Press.

Meyer, John W., John Boli, George M. Thomas and Francisco O. Ramirez. 1997. "World Society and the Nation-State." *The American Journal of Sociology* 103, 1 (July): 144-181.

Miller, John H. 1998. "Active Nonlinear Tests (ANTs) of Complex Simulation Models." *Management Science* 44, 6 (June): 820-830.

Odell, John S. 1993. "International Threats and Internal Politics: Brazil, the European Community, and the United States, 1985-1987." *Double-Edged Diplomacy: International Bargaining and Domestic Politics*. Peter B. Evans, Harold K. Jacobson, and Robert D. Putnam, eds. Berkeley: University of California Press. 233-264.

Olson, Mancur. 1965. *The Logic of Collective Action and the Theory of Groups*. Cambridge, MA: Harvard University Press.

Pepinsky, Thomas B. 2005. "From Agents to Outcomes: Simulation in International Relations." *European Journal of International Relations* 11, 3: 367-394.

Putnam, Robert D. 1988. "Diplomacy and Domestic Politics: The Logic of Two-Level Games." *International Organization* 42, 3 (Summer): 427-460.

Radcliffe, Benjamin. 1993. "The Structure of Voter Preferences." *The Journal of Politics* 55, 3. (August): 714-719.

Reed, Mary Lynn. 2004. "Political Modeling and Election Simulations." *Dr. Dobb's Journal* (October): 16-27.

Riker, William H. 1976. "The Number of Political Parties: A Reexamination of Duverger's Law." *Comparative Politics* 9, 1 (October): 93-106.

Ruggie, John Gerard. 1986. "Continuity and Transformation in the World Polity: Toward a Neorealist Synthesis." *Neorealism and Its Critics*. Robert O. Keohane, ed. New York: Columbia University Press: 131-157.

Schelling, Thomas C. *Micromotives and Macrobehavior*. New York: W. W. Norton, 1978.

Simon, Marc V. and Harvey Starr. 1996. "Extraction, Allocation, and the Rise and Decline of States: A Simulation of Two-Level Security Management." *The Journal of Conflict Resolution* 40, 2 (June): 272-297.

Snidal, Duncan. 1985. "Coordination versus Prisoner's Dilemma: Implications for International Cooperation and Regimes." *American Political Science Review* 79, 4 (December): 923-942.

Snidal, Duncan. 1991a. "Relative Gains and the Pattern of International Cooperation." *American Political Science Review* 85, 3 (September): 701-726.

Snidal, Duncan. 1991b. "International Cooperation among Relative Gains Maximizers." *International Studies Quarterly* 35, 4 (December): 387-402.

Waldrop, M. Mitchell. 1992. *Complexity: The Emerging Science at the Edge of Order and Chaos*. New York: Touchstone Books.

Wendt, Alexander. 1992. "Anarchy Is What States Make of It: The Social Construction of Power Politics." *International Organization* 46, 2 (Spring): 391-425.

Wilensky, Uri. 1998. NetLogo Voting Model. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, Illinois. Online resource available at http://ccl.northwestern.edu/netlogo/models/Voting.

Wilensky, Uri. 1999. NetLogo v. 3.0. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, Illinois. Online resource available at http://ccl.northwestern.edu/netlogo/.

Wilson, Rick K. and Carl M. Rhodes. 1997. "Leadership and Credibility in N-Person Coordination Games." *Journal of Conflict Resolution* 41, 6 (December): 767-791.