Chapter 7

Understanding System Dynamics: Simple Models of Complexity

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Introduction

The purpose of this paper is to make the case that systemic theorists in international relations have overlooked a way of thinking about the international system that is particularly well-suited to solving the analytic problems presented by that system. The tools of dynamic equation-based modeling are ideal both for generating the kinds of general-equilibrium predictions that systemic theories of IR should ideally produce and for testing those theories utilizing quantitative data.

The paper proceeds in six parts. The first discusses two traditions of systemic theorizing in American IR and argues that the possibilities inherent in a synthesis of the two are quite exciting but have been long overlooked. The second describes dynamic modeling and explains its utility in achieving such a synthesis. The third describes a new model of Great Power interaction, the "nested politics" model, which is designed to explore this potential. The fourth and fifth sections briefly hint at some of this model's capabilities in the realms of simulation and estimation. The sixth section compares and contrasts the previous sections with the companion contributions to this volume.

Systemic Schools of Thought

The main advantage to thinking systemically about the problems of international relations is that the international system actually *is* a system, and it acts like one.[1] In international affairs, two-party interactions are very often colored by the possibility of third-party involvement, three-party interactions must take into account the possibility of fourth-party involvement, and so on up the line. The systemic nature of international politics creates analytical problems that are difficult to resolve at best and intractable at worst. States and dyads cannot be neatly excised from the context that prompts their actions and analyzed in isolation from one another; moreover, the sum of a series of such analyses will fail to capture the essence of the whole system. Actions appropriate in a dyadic or triadic context may not be appropriate in a systemic one, and in a system actions may produce outcomes that can only be understood in the context of the larger picture. In short, no amount of sophistry, deft wielding of assumptions, or outright hand-waving can provide an adequate substitute for actually including the entire system, or at least its major actors, in the analysis.[2]

Unfortunately, although much international relations scholarship has been couched in the language of systems theory, few of the tools of the latter have actually been brought to bear on the problems of analysis. For this reason, systemic thinking has yet to realize its fullest potential. A review of the international relations literature on systems and systemic theories reveals two broad traditions, each of which seems for the most part to be uninterested in the other. This fact is a regrettable, as each contains some elements that could compensate for some of the shortcomings of the other.

The first broad systemic tradition in international relations theory consists primarily of research by scholars with strong backgrounds in mathematics or computer science and often a familiarity with systems theory as it is applied to other disciplines; these scholars have an interest in applying it to the study of international relations. Perhaps due to their role in politics in the nuclear age, physicists seem particularly prone to import mathematical skills to the study of politics, often on issues like arms races.[3] The first and most extreme form of this kind of systemic theory is general systems theory, a paradigm outlined in a series of lectures by Ludwig von Bertalanffy at the University of Chicago prior to World War II but popularized only after the war.[4] General systems theory was based on the premise that one can demonstrate similarities, or "isomorphisms," between the international system (or various national political systems) and entirely different kinds of systems, such as biological or physical ones. The work of Lewis Fry Richardson, a physicist and meteorologist who applied his skills to a voluminous attempt to gain a better understanding of the sources of deadly quarrels, is perhaps the most thorough and detailed application of this approach.[5] Although its adherents believed that it held the keys to nothing less than a general theory of international conflict, applications of general systems theory to international relations theory exhibited dangerous tendencies to obsess over analogies of questionable utility. Researchers who demonstrated the existence of such analogies often had a difficult time answering a single, devastating question: "So what?" Assessments of general system theory's promise for the study of politics faded fairly quickly after its inception.[6] With rare exception, this variant of systems theory did not survive the 1970s.

Most of the later research in this tradition has abandoned the idea of isomorphisms and seeks to understand the international system as a system—but in its own terms. Two broad traditions have followed general systems theory: equation-based modeling (EBM) and agent-based modeling (ABM). The main differences between these approaches lie in the means by which the models yield theoretical predictions (analytic vs. simulated), the nature of the outcomes (deterministic vs. stochastic), the units of analysis (variables vs. agents), and the extent to which spatial relations are assumed to create a context for interaction (typically not at all vs. typically very much). Such differences reflect the assumptions of the modeling techniques and as such can be overcome by a sufficiently determined modeler, so they should perhaps be thought of as comparative advantages rather than ironclad distinctions. In any event, both have proven to be remarkably versatile tools for understanding the behavior of political systems.

EBMs have been devised to model everything from the global system as a whole down to political dynamics at the sub-state levenl. Global models, such as the Simulated International Processes (SIP) project, initiated at Northwestern University by Harold Guetzkow (Guetzkow and Valadez 1981), and Stuart Bremer's Simulated International Processor (SIPER) and GLOBUS projects (Bremer 1977), were early demonstrations of the ability of EBMs to model relations among nations. Such models varied both in their complexity and the relative weight placed on the generation of insights via simulation vs. the testing of those insights with data; an outstanding early example of a model that pays careful attention to both is the "lateral pressure" theory described and tested in Choucri and North's *Nations in Conflict* (1975). The limitations of global models were illustrated in the controversy surrounding *The Limits to Growth* (1972), a spectacular book that

promised abrupt global catastrophe early in the 21st century if present population, industrialization, and pollution trends continued unchecked: subsequent criticism,[7] which focused on the sensitivity of the *Limits* model's conclusions to minor changes in the assumptions and perturbations in the parameters, alerted researchers to the fact that the uncertainty of one's conclusions grows exponentially with the number of assumptions. In more recent years, emphasis in EBMs in international relations has shifted away from all-encompassing global models that include large numbers of densely interrelated variables and toward a more narrow focus on the variables and relationships of interest.[8]

Athough EBMs such as Richardson's famous arms race model had been possible, at least in theory, since the invention of calculus in the mid-to-late 1600s, the spread of ABMs had to wait for intensive computing power.[9] The most prominent product of the ABM agenda to date was also one of the first: Robert Axelrod's *The Evolution of Cooperation* (1984) impressively derived general conclusions about the origins of cooperation from computer tournaments. Since that time ABMs have attracted a substantial following, though with the exception of such rare works as Lars-Erik Cederman's *Emergent Actors in World Politics* (1997) they remain underutilized in the study of international systems as understood by systemic IR theorists.[10]

The second systemic tradition in international relations theory is most famously exemplified by Kenneth Waltz's *Theory of International Politics* (1979), though it can arguably be dated at least to Morton Kaplan's *System and Process in International Politics* (1957).[11] It consists largely of scholars with strong international relations backgrounds who have applied language and concepts from general systems theory to the study of politics, both at the national and the international level.[12]

Unfortunately, as Barry Buzan, Charles Jones, and Richard Little point out in their 1993 discussion of Waltz's book, what passes for systemic theory in this tradition is often structural rather than systemic, meaning that it stops at the level of the structure of the international system. Clearly, international politics is unique, or nearly so, in that it takes place in an anarchic realm—one in which states must interact outside of the scope of formal and regular political authority. To make this point and to explore its implications in isolation, however, is to miss a critical fact: that the politics that takes place in this anarchic realm is first and foremost the interaction of states that are themselves organized political units, and that differences in the form of states' domestic political structures can be responsible for striking differences in how they engage in international politics. To stop there, however, is to miss an equally critical fact: that politics, by its nature, is a system that establishes the means by which we as citizens pursue our goals. Systemic theories incorporate the entirety of the system; structural theories focus only on the uppermost layer and "bracket" (that is, ignore) the rest.[13]

Moreover, as mentioned before, theories that fall into this category are notoriously imprecise. Waltz himself writes that "most theories of international politics are so imprecise that expectations of outcomes cannot be stated in ways that would make falsification possible" (Waltz 1979, 13), but his version of balance of power theory derives the expectation that "balances of power recurrently form" (124) from the premises that states in an anarchical system "are unitary actors who, at a minimum, seek their own preservation and, at a maximum, drive for universal domination" (118). It is not at all clear how the prediction follows from these premises.

Although students of international relations have adopted the forms of systems theories by paying homage to concepts like feedback and equilibrium, they eschew the substance by failing to specify their theories in such a way that those concepts can be meaningfully applied. Their work often remains, as Weltman (1973) rather colorfully put it, an exercise in "metaphoric hypertrophy." Despite the fact that the application of mathematics to international systems was a major growth industry in the 1960s and 1970s, for example, Waltz seems either ignorant or disdainful of the entire literature, which is glaringly omitted from his *magnum opus.* Although systems theory and cybernetics are not slighted *in the abstract*—indeed, Waltz credits a handful of authors on those topics (fn., p. 40) with having influenced his thinking about a systemic theory of international politics—, the authors who have actually applied them to the study of international politics are almost entirely ignored, despite the fact that Waltz is clearly not unaware of some of their other research. Karl Deutsch's work with J. David Singer on the subject of multipolarity is mentioned in passing, but his work in *The Analysis of International Relations* on the relationship among state power, state interests, elites, and the making of foreign policy, much of which, it should be noted, would fit quite well with the model described below, goes unmentioned.[14] Stuart Bremer's work with J. David Singer and John Stuckey on capabilities, uncertainty and war is discussed, but Bremer's work on systemic politics in *Simulated Worlds,* prominently published not two years before Waltz's own book, is unmentioned, despite its obvious relevance.[15] Even after the passage of two decades, Waltz's most prominent systemic critic and most outspoken realist successor[16] seem no more eager than he to engage the work of those who have applied the tools of systems theory to the analysis of international systems.

At the same time, the latter group rarely engages the former on their own terms. Although systems approaches are flexible enough to be applied to phenomena as diverse as "turtles, termites, and traffic jams,"[17] the number of attempts to apply it to existing systemic theories of international politics is remarkably small. Even Axelrod, whose work is foundational in the study of international institutions, rarely addresses realism (institutionalism's *bête noire*) directly. Those works in the EBM or ABM tradition that do specifically address mainstream arguments are a remarkably small subset of their respective literatures.[18]

As a result of this intellectual segregation, mainstream theorizing about the international *system,* though it is open to influences from sociology and history, remains little influenced by *actual systems theory,* or even by international relations research that is informed by it. This is an unfortunate fact, because dynamic systems theory, and in particular the tradition of dynamic modeling, holds forth the possibility of addressing this issue, which has become one of the thorniest problems facing systems theory in international relations.

Dynamic Modeling

Systemic theory is characterized by a considerable degree of interaction, endogeneity, and complexity. As a result, it is an unusually poor candidate for verbal theorizing and testing: human intuition is not always at its most impressive when dealing with issues of interaction and complexity, and endogeneity among stochastic phenomena can present a host of ugly issues for inference. Moreover, qualitative analysis of systems tends to be

complicated by the fact that so many of the relevant variables vary contemporaneously, raising difficulties in assessing relative causal weight. In short, the nature of the theory, and of systemic theory in general, suggests that quantitative techniques in general, and dynamic modeling in particular, are worth exploring as a means of understanding systemic dynamics. Yet, as the previous section demonstrates, equation-based models in general remain underutilized as a means of understanding systemic dynamics.

This section examines the development of dynamic modeling in a related discipline, macroeconomics, as a way of exploring the utility of the approach in that context; subsequently, I offer some thoughts about the shortcomings of macroeconometric modeling, both in its own right and as a technique for understanding human behavior more generally; I then suggest three lessons that dynamic modelers should consider when applying such techniques to the study of political systems.

Macroeconomics, Dynamics, and General Equilibrium

As early as 1874, Léon Walras had conceived of a notion that would evolve into what is now known as general equilibrium theory.[19] The motivation for general equilibrium theory corresponds quite closely to the motivation for systemic IR theory, namely that the behavior of one actor has an impact on the behavior of the rest. The goal of capturing the complex implications of general equilibrium theory, in turn, gave rise to the field of macroeconometric modeling. When the economist Jan Tinbergen was director of the Central Planning Bureau of the Government of the Netherlands from 1945-1955, he undertook the impressive task of deriving and testing a macroeconometric model of the

Dutch economy. The results were promising enough that, before long, macroeconometric models of national economies had been established across the globe, from the United States and United Kingdom to Japan to India and to Latin America, and initiatives like Project LINK were generating comprehensive international models.[20]

Macroeconometric modeling, like dynamic modeling more generally, involves in essence an attempt to describe the behavior of a system by describing the interrelationships among its parts utilizing a system of equations. The parts can be groups, firms, organizations, sectors, and so forth; the method is (mostly) ontologically innocent, in that nothing inherent in the method limits its empirical scope save the requirements of estimation.[21] Once the model of the economy has been constructed and the necessary data obtained, the system of equations is estimated. In contrast to standard practice in microeconomics and political science, the statistical significance of the estimated coefficients are thought to be of little use in empirical evaluation of the model; rather, the coefficients are used to generate a simulation of the economy as a whole, and the extent to which the simulation maps to the actual performance of the economy is assumed to be the yardstick by which the quality of the model is judged.

Macroeconometric modeling possesses a wide range of characteristics that makes it very intriguing from the point of view of systemic theories of international relations. First, as already mentioned, the focus is on general rather than partial equilibrium: all of the major actors in the system are incorporated into the model and contribute to the outcomes of interest. Moreover, within the time-series framework of a general equilibrium model, reciprocal causal relationships can be captured in a straightforward way. Because systemic theory implies reciprocal causal relationships, and because such

relationships cannot be understood at a single point in time, a systemic theory *must* be dynamic.[22] General equilibrium models easily encompass such relationships.

The quantification involved in generating macroeconometric models has implications that have been repeated *ad nauseam* in the ongoing squabble between qualitative and quantitative methodologists and need not be recounted in detail here. On the positive side of the ledger, the act of generating a mathematical model forces the theorist to be explicit about the causal linkages among variables in the theory, and the act of testing it compels both uniformity and clarity of measurement, which may or may not be present otherwise. On the negative side, the much-touted clarity of mathematical models does not guarantee comprehension, especially in the case of complex models, which even the most mathematically adept might find tedious to verify; the need for data tends to draw scholars toward metrics that are available and convenient as well as theories that utilize them.

Perhaps the most impressive feature of macroeconometric models, however, is that they can serve both as a formal modeling enterprise that allows the researcher to see which conclusions follow from theoretical premises and how, and as an econometric test that assesses how well or poorly the outputs of the hypothesized process map to those of the real world. Indeed, these characteristics are inseparable: the dynamic time-series equations that comprise the model also serve as systems of difference or differential equations that can be used both to check the model's implications and to evaluate its fit to the real world when it is run using estimated coefficients.[23]

All of this is not to say, of course, that the method is without its detractors. In the field of macroeconomics, macroeconometric modeling has come under fire for its

predictive lapses, especially in the case of underpredictions of large changes (the recessions of the 1970s and 1990s, for example, and the boom of the 1980s). Empirically, it has been argued that the stochastic element of economic behavior swamps the systematic component, so that the enterprise stands little chance of success even under the best conditions.[24] The econometrics of macroeconometric models have also been challenged: Sims (1980) argues that vector autoregression (VAR) techniques would be preferable, but advocates of equation-based dynamic models have replied that VARs' atheoretical nature and the inefficiency of their estimates have made them unsatisfying both as explanatory models and as predictive models. As one prominent recent review of the literature concludes, "structural macroeconometric modelling still remains the most promising approach to understanding macroeconomic behaviour generally."[25]

Lessons for Systemic Theorists

To a theorist seeking to understand the workings of the international system, what lessons can be taken away from this brief survey of macroeconometric modeling? I would point to three.

The first lesson has to do with the relationship between modeling technique and subject matter. As Almond and Genco (1977), borrowing Karl Popper's metaphor, pointed out three decades ago, phenomena vary in the degree to which they are "clocklike" or "cloudlike" in nature—i.e., deterministic and predictable, or essentially stochastic—and human affairs fall somewhere between the two extremes. Incentives, contexts, institutions and norms push behavior in certain directions, but rarely with such

force and clarity that the behavior of the actors involved becomes as predictable as that of a falling stone or an orbiting moon. Building large and complex systemic models of physical systems is appropriate, because in many cases they lend themselves well to prediction once a certain level of complexity has been reached; in the social sciences, by contrast, there is most likely an upper limit to the precision and quality of forecasts, and trying to surpass that limit produces diminishing or illusory returns.

Indeed, macroeconomists seem to be arriving at precisely this conclusion. Neely and Sarno (2002) examine the question as to why, even with substantial amounts of data available, exchange rate forecasts typically fail to predict much of the actual variance in exchange rates, even a single period into the future; many of the answers that they offer boil down to failures of theories of rational behavior to generate comprehensive predictions of human behavior. Even Fildes and Stekler (2002), who defend macroeconomic models, concede that their forecast horizon is dramatically limited.

The second lesson has to do with the tradeoff between complexity and parsimony. Macroeconometric models, and many of the early world-systems models built in their image, are not just complex but massively complex, encompassing many thousands of variables and untold numbers of screens full of code.[26] Such massive modeling efforts, while they may generate reasonable predictions during normal periods, often do little to aid understanding. Consider Jorge Luis Borges' parable entitled "Of Exactitude in Science," which, quoted in its entirety, reads as follows:

> ...In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of

> the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it. The following Generations, who were not so fond of the Study of Cartography as their Forebears had been, saw that that vast Map was Useless, and not without some Pitilessness was it, that they delivered it up to the Inclemencies of Sun and Winters. In the Deserts of the West, still today, there are Tattered Ruins of that Map, inhabited by Animals and Beggars; in all the Land there is no other Relic of the Disciplines of Geography (Borges 1998).

The lesson, of course, is that beyond a certain point the complexity of a model makes it uninteresting as a description of reality: as it approaches the complexity of reality itself, its value disappears. Political scientists, driven more by the desire to understand the international system than by a desire to capture every last hiccup in every time series, would do well not to emulate such theoretical fecundity, lest they meet the fate of Borges' geographers.

The third lesson, closely related to the second, has to do with the tradeoff between explanation and prediction. While in most social science applications, the two are complementary goals, in the context of dynamic models of behavior there is a pronounced tension between the two. Seeking to explain the behavior of a system involves endogenizing as many of the variables in the system as possible, but, as Ashley

(1988) points out, the existence of endogenous variables on the right-hand side renders forecasts almost instantly worthless due to the compounding of uncertainty.

Faced with such a situation, what is a dynamic modeler to do? Bankes (1993) suggests a modeling approach suitable to the subject matter: given that forecasting in social systems is an uncertain business at best, we should focus less on the use of large, comprehensive models for prediction and more on the use of small, exploratory models for improving our insights about the subject matter. This, it seems to me, is precisely the right approach: to generate models that are small enough that they can be readily comprehended by most specialists, yet complex enough that their workings illuminate something about the subject matter that would not have been readily grasped with unaided intuition. The purpose of such a model is not pinpoint prediction but rather to serve as an aid to the analyst's understanding of a given situation, a means of understanding the likely implications of changes in the world and a test bed for fine-tuning that understanding. Out-of-sample forecasting should remain an interesting exercise, but not for policy purposes; rather, the non-experimental nature of the data in international relations calls into question causal interpretations of standard econometric models, and one of the ways to address this issue is to test a model's applicability to data that were not utilized to generate its estimated parameters (see, for example, deMarchi et al. (2004), and the estimation section below).

This more proscribed, less ambitious, but ultimately more satisfying modeling exercise is perfectly suited to the dynamics of the international system, in which the complexity of the interactions among states rapidly outrun unaided intuition. The next

section describes a model designed to capture those dynamics, and the following sections briefly hint at its utility.

The Nested Politics Model

To illustrate the utility of this modeling philosophy, I will offer a much-abbreviated version of the model at the heart of my own current research project, both because I know it well and because I created it in a conscious attempt to achieve precisely the synthesis that I have described in previous sections.[27] Once I have described the model, I will briefly illustrate its capabilities in the realm of theoretical simulation and empirical estimation. The results show that it provides an excellent vehicle for capturing the theoretical relationships of interest in this particular systemic theory and, by extension, in systemic theories more generally.

In a nutshell,[28] the nested politics model argues that the nested structure of political authority within the international system—individual autonomy nested within domestic hierarchy nested within international anarchy—is a primary engine for change, both in the behavior of the main actors and in the structure of the international system.

The model proceeds in three stages. In the first, the constituents in a given state—each of whom possesses a *worldview,* that is a set of structured ideas that determine the dimensions of the structure of the international system that are deemed relevant to a state's security policy, the emphasis that is put on each of those dimensions, and the ideal state of the world along each dimension—look out at the world and are, to some extent, dissatisfied with it. The present status of the world along the dimensions emphasized by

the citizenry's worldview, relative to its ideal points, determines citizens' preferences for action.[29] The farther the present system is from the state's ideal point, the greater the citizenry's level of dissatisfaction,[30] and the greater its desire for action to redress the present situation.

In the second stage, the desires of the citizenry are conveyed to the leadership via a preference-aggregation mechanism. This process is captured with a straightforward probabilistic voting model, in which uncertainty exists both on the part of the constituency about the benefits of the candidates' platforms and on the part of the candidates about the behavior of their constituents. Constituents may be ill-informed; candidates might not be able to count on their support even if they were because they may be incorporating idiosyncratic factors into their decision calculus. Constituents are therefore assumed to support a candidate with a probability that increases as the candidate's platform's utility to them increases and decreases as the candidate's opponent's platform's utility to them increases.[31] Under these conditions, the uncertainty surrounding constituents' behavior smoothes out the relationship between candidates' positions on the issues and the support that they receive, making it impossible for leaders to find "issue niches" that afford a temporary advantage and banishing many of the famously grim conclusions of public choice theory. Instead, a single optimal position emerges.[32] Under the relatively general assumptions described above, this position is the one that maximizes the mean of the constituents' utilities.[33]

It is important to bear in mind that a constituency can place "demands" on the leadership without ever uttering a word. Just as the course of a lightning bolt is determined entirely by tiny differences in resistance among the countless air molecules

that surround it, a constituency that makes no actual policy demands whatsoever but merely reacts to policies as they are enacted (or debated) guides politics along the path of least resistance. Although this form of passive compellance is most apparent in democracies in the modern age of near-instantaneous public opinion polls, it is an inherent feature of government, however large or small the constituency.[34] The worldviews of constituencies shape the policies of elites, not by any direct form of coercion, but passively—by virtue of the fact that satisfying one's constituency also happens to be the best way to get into office and stay there.

In the third stage, once a state's collective preferences have coalesced and the constituency has issued a demand for action on the part of the leadership, leaders must choose a level of foreign policy activity for the state. While positions on domestic economic matters often boil down to taking a stand on the question of how much should be given to (or taken from) whom, in the case of foreign affairs leaders must choose how active the state will be in pursuing the constituents' *desiderata*—how hard to work to maintain the balance of power, perhaps, or how much effort to expend in fomenting revolution abroad. Inactivity on the part of leaders in the face of demands for action will be penalized because it will be viewed as neglectful of the national interest. Activity in excess of that demanded by the constituency will be penalized because it will be viewed as a diversion of resources away from more important tasks.[35] The leadership is assumed to be free to take whatever level of action it chooses, though the extent to which leaders' actions are effective is limited both by the realized capabilities of the state[36] and by the actions taken by the leaders of other states.

The net result of the actions of the leaders of all states is a change in the status of the system. Once that change has occurred, the cycle of activity begins anew: the state's citizenry observes the system through the prism of its worldview, it makes demands on its leaders, those demands are aggregated, leaders act on them, those actions collectively have an impact on the status of the system, and so on.[37] The formalization of the model, along with a brief primer on differential equations, can be found in the Appendix.

Analytic Results via Simulation

The Effects of Socialization

How might such a model be adapted to capture processes of interest to students of systemic theory? The bare-bones model described above makes no assumptions about relationships among variables other than those already described, but in order to tease out the implications of other hypothesized systemic processes it is possible to "hard-wire" additional theoretical assumptions into the model and examine their implications. One such example is offered here: the effects of socialization. The conclusion on offer is one that constructivist scholars might find counterintuitive, and perhaps even morally repugnant, namely, that a simple process of socialization can be shown to aid in the process by which a balance of power is produced.

Wendt (1999, 170), *inter alia*, points to socialization as the process by which identities and interests are formed; Klotz (1995), who highlights the role of international norms in the definition of American interests in South Africa, notes that "constructivist theory...claims that agents and structures reconstitute each other in an iterative process" (478). What this implies, in terms of the nested politics model, is that the worldviews of

states converge over time. The dynamic model described herein provides the perfect opportunity to flesh out the implications of such a process.

It is possible to model the constructivist notion that the international system socializes its actors by making worldviews into state variables rather than parameters and having them converge toward the systemic average over time. There is little in the theory to explain when or how convergence ends; indeed, if socialization is ongoing and not interrupted by any countervailing force, the process of convergence would only end when the process of socialization produces no further change in worldviews.

The effects of socialization should also change the ideal points of the states' constituencies. If we relax the assumption that c_{nm} is constant across states but retain the assumption of a constant preference aggregation function $n_i(\bullet)$, it is fairly straightforward to specify a Markov process that describes transitions from one preference "state" to another in such a way that the various c_i converge to a common frequency distribution.

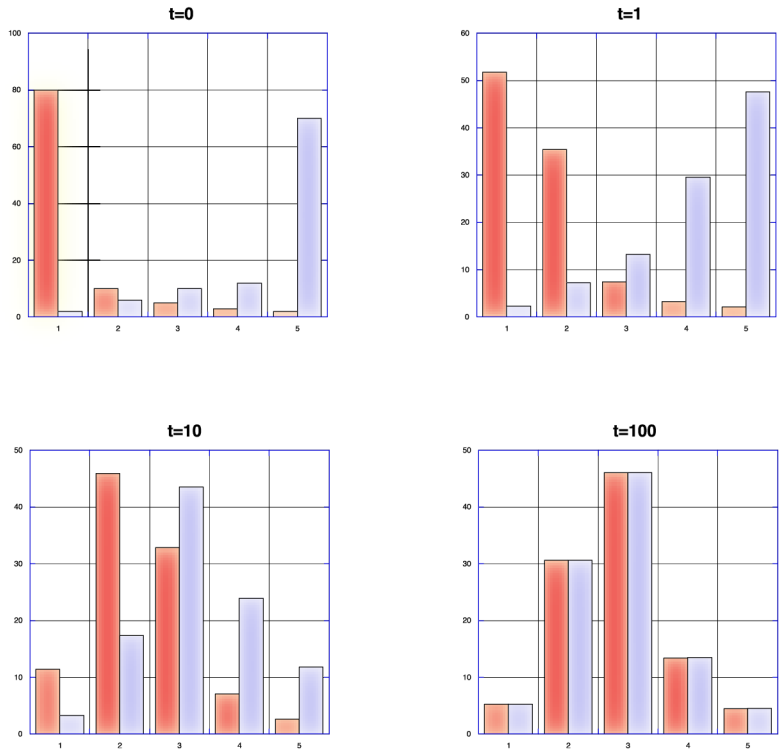

Figure 0.1: Simulated Markov process describing effects of socialization on distributions of ideal points for constituencies in two states *i* and *j*

To see this point, imagine five preference states, each corresponding to possession of an ideal point in a given fifth of the unit interval. Specify that citizens of *i* compare the relative frequencies of their own state and adjacent states across countries. (Denote the frequency of state *p* in country *i* as f_{cip} and the frequency of adjacent states as f_{ciq}.) Citizens of *i* are socialized when they are drawn away from their existing states and toward adjacent preference states that are more popular in other states than they are in *i*.[38] Under those circumstances, as Figure 0.1 illustrates, the frequency distributions c_{im} of the various actors also converge. Given that the preference aggregation function is assumed to be the same for both states, the results regarding defensive realism (above)

apply, and a balance of power is assured, assuming equality of realized capabilities. The balance will be upset in proportion to the extent to which the distribution of realized capabilities is unequal, but in a world of rough equality of realized capabilities, the socialization implied by constructivism should produce a balance of power.

I have illustrated the results of this process in Figure 0.2. The world depicted in this graph is one in which two states, *i* and *j*, compete over resources in two spheres, the economic sphere *e* and the *realpolitik* sphere *r*.[39] State *i* is the kind of state envisioned by realist scholars, i.e., one that concerns itself overwhelmingly with the accumulation of power resources, though it still devotes 20% of its activity to economic matters. State *j* is what Richard Rosecrance (1986) calls a "trading state," one that almost exclusively emphasizes economics rather than *realpolitik* concerns in its foreign policy (in this case, *j* devotes only 10% of its activity to matters of defense). It is assumed that this is a strictly bipolar system, that is, that realized capabilities for the two states are equal, and that each would be happiest in sole possession of all of the resources available in the system.

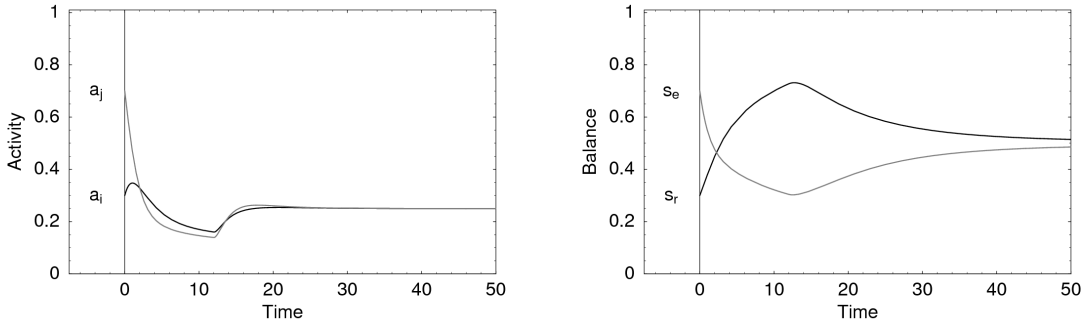

Figure 0.2: Constructing a balance of power?

In the first part of the simulation, the structural dimensions of the system diverge. In the right-hand graph, in which the vertical dimension measures the percentage of systemic resources possessed by state *i*, we see that *i* gains in *realpolitik* resources but loses in economic resources. This result follows from the relative emphasis of the two states on the two different structural dimensions: each gains what it most wants. As the state of the system becomes more to their liking, the dissatisfaction of the citizenry and the subsequent demand for activity decrease. As the left-hand graph demonstrates, the result is a decrease in levels of activity for both states.

At time 12, however, a process of socialization begins in which the emphases placed by the two states on the different dimensions of the system start to change. Over time, each state's worldview becomes more like the other's.[40] As the states' worldviews change, their constituencies come to emphasize the same desiderata in the demands that they place on the leadership. The leadership, in turn, complies by increasing its level of activity and changing the thrust of its policies to capture more of its constituency's newly-relevant resources. In the end, worldviews are constant across states, and the result is an equal distribution of resources across spheres. Under these conditions, curiously enough, the process of socialization has produced balances of both economic and *realpolitik* resources.

The value of such simulations lies both in their ability to determine which outcomes follow logically from a given set of theoretical assumptions and to illustrate how those outcomes change if the theoretical assumptions are altered. Lacking socialization, for example, the initial conditions would have produced highly asymmetrical distributions of economic and *realpolitik* goods and very satisfied (and

hence inactive) actors; the model permits us to chart the trend up to time 12 and see how remarkable the change is thereafter, once the process of socialization begins. These features are not especially novel: indeed, they are the primary justification for any formal mathematical model and are, arguably, the only aspects that make the math worthwhile. Nevertheless, they are especially valuable in the context of systemic theory, where the implications of a change in one part of the system can be very complex and impervious to discovery by brute intuition.

Admittedly, the model of socialization offered here is highly simplistic and lacks some of the features of existing theories of socialization, such as an explanation for what makes some ideas more popular than others: in this model, the transmission of ideas is about as complicated as the transmission of diseases among perfectly mobile populations. Its simplicity is intentional, the goal being to understand the complex implications of simple assumptions. If, however, the lack of realism underlying the assumptions serve as a prod to further theorizing and exploratory modeling, so much the better.

Empirical Results via Estimation

The empirical implications of the model can be most fruitfully evaluated in two ways. The first is to elaborate specific theoretical models that are appropriate to various periods in history, translate them into a statistical models, gather the necessary data, and run a large-N test of the system of equations implied by theory. The second approach involves finding periods in which substantial changes occur in one variable, using the model to tease out the implications for the remaining variables in the system, and engaging in

historical case studies to evaluate the relevant prediction(s). What follows is an example of the first approach; the second is illustrated elsewhere in the project.[41]

Historical Context: 1815-1914

European international relations in the period between the Napoleonic Wars and World War I consisted, broadly speaking, of activity on two levels. The first had to do with everyday *interactive* politics—commercial interactions, territorial disputes, imperial rivalries, and so on. The second level was, on a very primitive level, *regulatory:* it was an explicit attempt to create an international system which would prevent the frictions generated at the first level from escalating to major war.

The impressive thing about the behaviour of the Powers in 1815 is that they were prepared, as they had never previously been prepared, to waive their individual interests in the pursuit of an international system. This fact is not rendered any less impressive by the recognition that they were prepared to waive their individual interests because it was in their individual interests to do so.[42]

Schroeder (1994) also argues that this change constituted a fundamental "transformation" in European politics; Buzan et al. (1993, 330, 347), citing Hedley Bull and Adam Watson, equates this state of self-interested self-regulation to an international society. Similar forms of regulation take place in human societies when, as is almost always the case, people realize that their interests will clash from time to time and agree to set up some form of mechanism (judicial, executive, legislative) at the meta-interaction level to defuse the resulting conflicts.[43] The European regulatory mechanism was crude

when compared to, say, domestic political institutions, but it nevertheless performed some of the same functions.

One form of regulatory politics was based on the notion that war could be prevented if countries could be rendered unable to profit from it. Accordingly, regulation was to be accomplished by maintaining the balance of power. The balance of power had two main incarnations: the *static* version of balance-of-power theory emphasized equality of capabilities among units, whereas the *dynamic* version of balance-of-power theory emphasized equality of capabilities among coalitions.[44] To the believers in the static version, "balance of power" was a noun: if the capabilities of states could be made equal, the balance would deter aggression. To those desiring a dynamic balance, "balance of power" was a verb: the proper way of dealing with a threat was to balance against it. Regardless of the form of balance sought, the emphasis was on the distribution of latent material capabilities of the Great Powers.

A second regulatory mechanism focused on shared conservative (or "legitimist") values as a guarantor of peace. The logic was fairly straightforward: the French revolution, based on liberty and constitutionalism, had snowballed into a general war of immense proportions. Future revolutions of the same sort could therefore not be trusted, so the best guarantor of peace was continued conservative rule. Whereas the balance of power focused mainly on opportunity, this mechanism focused primarily on willingness.[45] Kissinger (1994, 77) neatly captures the essence of the distinction when he writes that "the balance of power inhibits the *capacity* to overthrow the international order; agreement on shared values inhibits the *desire* to overthrow the international

order." Here, the emphasis was not on capabilities but rather form of government: liberalism and liberalization were seen as the most serious threats to the peace.

The structure of the international system throughout this period, therefore, consists primarily of two dimensions: the balance of power and the "balance of ideology," or the extent to which liberal government had spread throughout the continent.

Results

The details of the estimation of the model are neither succinct nor especially relevant to this brief illustration. As they have been elaborated elsewhere,[46] I will limit myself to the briefest of descriptions. Information on the capabilities of states was gathered from the Correlates of War project. Realized capabilities were modeled as the average of a state's military spending and its military personnel, both taken as fractions of the overall Great Power total. Latent capabilities was modeled as an average of iron/steel production and urban population, again taken as fractions of the overall Great Power total. The balance of power was then calculated as the standard deviation of the distribution of the Great Powers' scores on this latent power measure. The measure of the spread of liberal government was derived from the Polity IV project and is nothing more than the average of the non-missing Polity democracy scores for all European states in the period. The remaining variables, comprising the levels of activity of the various states, the ideal points of constituencies and leaders, and the degree of salience of each systemic dimension, were measured via a three-stage survey of academic historians that was completed in the spring of 2005. The model, consisting of seven equations (two structural

equations, derived from equation 7, and five actor-level equations derived from equation 8) was then estimated[47] using three different estimators—ordinary least squares regression, three-stage least squares, and full-information maximum likelihood—that reflect different sets of assumptions about the data. As none of these assumptions (regarding, for example, correlations among error terms, or the distribution of the error terms) was in any way relevant to the model being tested, none was considered *a priori* to have been preferable. A comparison of the results using Thiel's inequality coefficient, a standard tool in macroeconometric analysis, suggested that the assumptions of ordinary least squares did the least violence to the truth, followed closely by three-stage least squares and at a considerably greater distance by full-information maximum likelihood. Ordinary least squares was therefore taken to be the estimator of choice.[48]

As an exercise, I have charted the actual series along with one-period-ahead forecasts in Figure 0.3. The actual historical series is in black. Because simple point predictions do not capture the uncertainty surrounding the estimate, I have represented the forecasts as a grey zone which lies between the upper and lower 95% confidence intervals. To be clear, I started by estimating the model on the data from 1815 to 1835 and then making predictions for 1836; I then estimated the model on the data from 1815 to 1836 and made predictions for 1837; and so on down the line, iterating the process until I reached 1914.[49] Because the predictions are intended as a test of the model's ability to capture trends in out-of-sample data, rather than as a simulation of the sort of real-world forecasting ability sought by microeconomists, the actual one-year-ahead values of the right-hand-side variables, rather than forecasts of those variables, were utilized.

A few characteristics of the forecasts are immediately apparent. First, nearly without exception, the forecasts based on twenty years or so of data are terrible, but they are terrible in interesting ways. The forecasts fluctuate fairly dramatically between high-certainty and low-certainty forecasts, and the early years contain quite a few low-certainty forecasts. Indeed, one would be hard-pressed to offer a less specific forecast than that for Austria in 1848: looking forward one year, the model has absolutely no idea what will happen.[50]

After about 1860, however, the forecasts quiet down, becoming in fact fairly reasonable, though a few spikes remain. After 1880, some of the forecasts become surprisingly good, and low-certainty years, while not entirely gone, are far more rare. Some series are forecast with considerably greater certainty than others: predictions for France remain stubbornly noisy through the end of the period, for example, while predictions for the balance of ideology become shockingly precise (and on the whole quite accurate). In short, although it requires 50 or 60 observations in order to do so (a requirement that people working with monthly data would hardly find onerous!), the model does eventually settle down and start to make very reasonable out-of-sample forecasts.

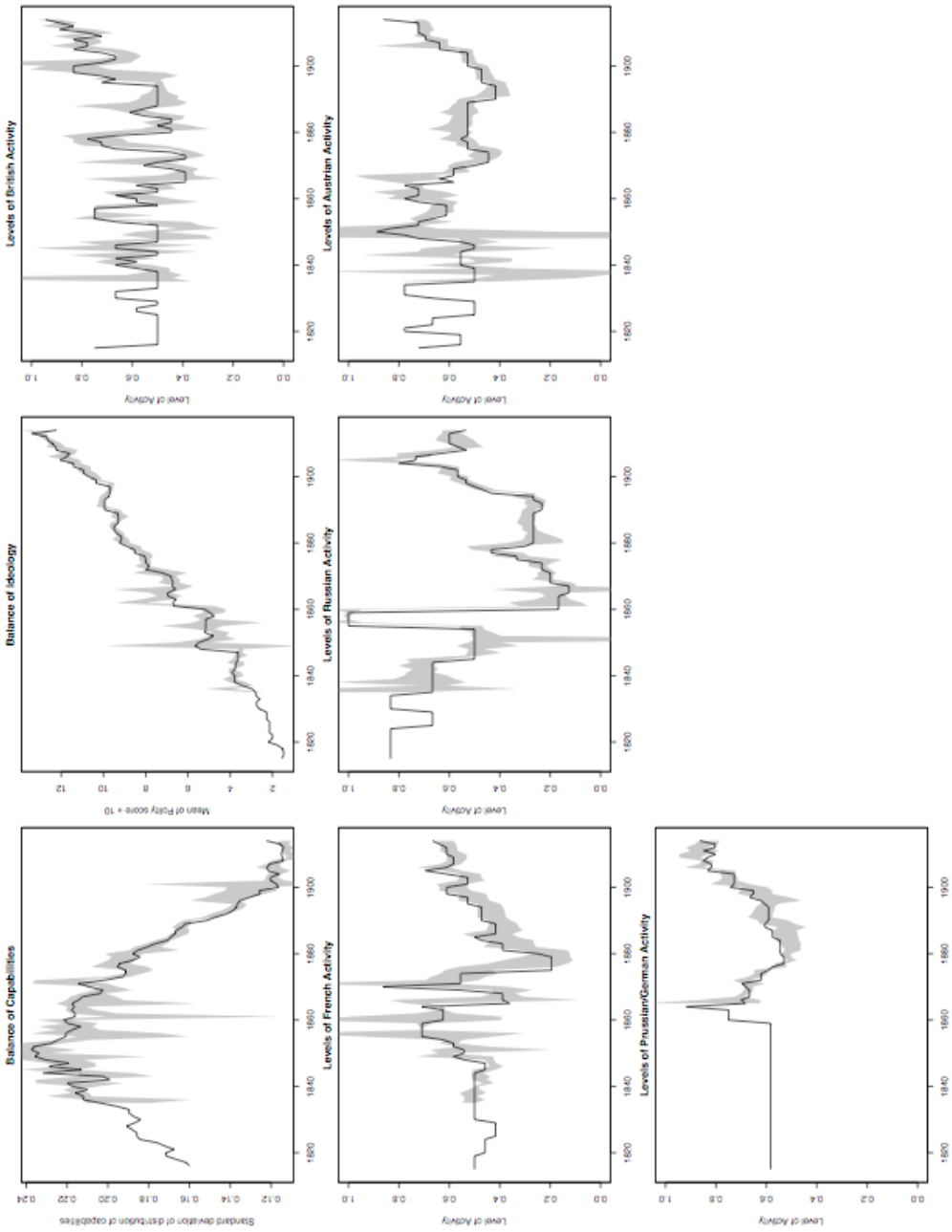

Figure 0.3: Balances of power and of ideology and levels of state activity: actual values and 95% confidence intervals for one-forecast-ahead predictions.

This exercise suggests that, within limits, dynamic modeling may have substantial value in helping us understand the behavior of social systems. The theory upon which this particular model is based is, by macroeconometric standards, laughably simple: rather than thousands or tens of thousands of equations, it contains only seven, and once the terms on the right-hand side have been multiplied out, the number of variables never exceeds a dozen. Estimation is via OLS and requires no block-recursion or other heroic solution to endogeneity issues. It cannot forecast wars, and there are certainly points at which an abrupt spike takes it by surprise. Yet it is difficult to avoid the conclusion that there is something of considerable value here. The model correctly captures both the central trends in activity and, in gross terms, the timing and direction of changes in levels of activity. Moreover, it does a very reasonable job of capturing trends in both the balance of power and the balance of ideology. Especially compared to other systemic theories, which are notorious for providing ambiguous predictions when they provide predictions at all, it represents a substantial step forward in our understanding of the dynamics of the international system.

Dynamic Modeling in Perspective

The example just offered and the companion pieces in this volume invite some rumination regarding the fundamental similarities and differences among systemic perspectives. As dynamic modeling is a method rather than a theoretical paradigm *per se,* the usual caveats regarding apples and oranges clearly apply; nevertheless, it is interesting to speculate on the varieties of fruit salad that might result from their judicious

intermingling. Moreover, the nested politics model as a specific systemic theory in its own right has some interesting theoretical points of contact with the others that merit discussion.

The most obvious comparison that one could make is with Cederman's complex adaptive systems approach, and here, the differences are substantially less glaring than one might at first glance think. There is no reason, for example, that a dynamic model cannot simulate a simple Markov process, such as the one illustrated in Figure 0.1, and such processes are simply an equation-based way of modeling the large-scale results of the interactions of agents at the micro-level. Indeed, simple sets of differential equations have been designed to capture the spread of diseases, the oscillation of predators and prey, etc., etc.—all phenomena that one might reasonably seek to capture in an agent-based model.

There are, nevertheless, some differences in the ease with which the two approaches can be applied to different phenomena, and there are basic differences in the manner in which systematic and stochastic (random) components of the models are thought to relate to one another. In the former case, the two different approaches clearly do not lend themselves equally well to modeling exactly the same phenomena. As Cederman notes, agent-based models seek a generative perspective rather than searching for causal laws.[51] Similarly, agent-based models are typically designed to be explicitly spatial in nature, a fact that can be beneficial or problematic depending on whether or not the model in question contains important spatial elements. In the above example, modeling the geography of the system might produce interesting insights, or it might require a number of ancillary assumptions that detract from the clarity and utility of the

theory. In this case, it proved quite possible to model quasi-spatial phenomena such as the distributions of capabilities and ideology implicitly rather than explicitly.

The difference in the approaches of the two techniques to randomness is a bit more subtle but is nevertheless crucial: agent-based models often incorporate randomness as an important part of the theory—as when an agent moves in a certain direction with a given probability, or a conflict among states is resolved in a certain way with a given probability[52] —, while equation-based models see it as the result of forces external to the theory. As a result, while agent-based modelers often focus on the distribution of outcomes across multiple "runs" that differ only in the role played by chance, dynamic modelers typically focus on the relationship between one set of predictions and one set of outcomes.

Again, each approach has its advantages. By looking at entire distributions of possible outcomes, or even comparing distributions of outcomes under different assumptions about the role of chance, agent-based modelers can make quite a few interesting statements about the relationship between randomness at one level and order at the next. Equation-based models, by contrast, lend themselves most readily to capturing central tendencies—equivalent, perhaps, to the average of thousands of iterations of an agent-based model—under the assumption that deviations from that central tendency are to be chalked up to "unexplained variance," a category that includes measurement error, chance, the cumulative impact of many small unmodeled causes, and so forth.[53] While this approach foregoes the more nuanced understanding of chance as an important causal phenomenon in its own right, it nevertheless sensitizes the researcher to some of the grave threats of inference that can result from complex combinations of

randomness and order in the form of correlations among error terms—that is, endogeneity bias, selection bias, simultaneity bias, and so forth.[54]

In all, while hard-core partisans will surely trumpet the unconditional and uncritical use of one technique over the other, a careful assessment hardly warrants such a conclusion. The answer to the question of which of the two is the most appealing approach to systemic theorizing, or to modeling in general, depends heavily on which aspects of reality the researcher wishes to capture and how he or she wishes to incorporate them into the analysis.

The most obvious points of contact with the remaining literature described in this collection would be with the leadership long cycle school, represented by Thompson, and the world-systems approach of Chase-Dunn. Here, few substantial differences save historical scope and the extent to which the microfoundations of the relationships between agents and structure are modeled explicitly need be mentioned, and the latter, in models that reach back to the 15th century, should come as no surprise. It is also worth noting, given the interest of both schools in explaining conflict, that the main emphasis of statistical tests in these two schools tends to be the relationship between structure and conflict, rather than between agents and structure, as in the above model.[55] The fundamental ontological and epistemological orientations of the three approaches are quite similar, suggesting that each could fruitfully inform the others.[56]

Indeed, Choucri and North (1975) remains an excellent illustration of the promise of cross-fertilization. Choucri and North's "lateral pressure theory" follows in the tradition of the world system theorists' attention to the relationship among population, technology, resources, and conflict, but the authors limit the historical range of the study

to periods in which concrete data can be found. Despite the passage of three decades, the resulting statistical tests, simulations, and forecasts would be quite familiar to macroeconomists.[57]

Not as obvious, but perhaps even more extensive, would be the links between the nested politics model described above and Nexon's extension of structural realism to incorporate the system of international authority. Indeed, the starting point for both is the relationship among anarchy, domestic systems, and foreign policy that is (perhaps generously) attributed to structural realism by Nexon; they depart substantively in that the nested politics approach seeks to flesh out the structural and the domestic-political dimensions of the story, whereas Nexon focuses on elaborating the additional structural variables of universality (or not) of legitimating principle and substitutability (or not) of systemic leadership. In practice, the differences stem from somewhat divergent understandings of the requirements of systemic theorizing: Nexon seeks to maintain the structural purity of the realist approach by avoiding reductionism, whereas I focus more on the relationships between agents and structures and happily court, even embrace, partial reductionism in an attempt to capture them. In principle, nothing precludes a dynamic approach to modeling and testing the former elaboration (save, perhaps, the considerable endogeneity suggested by Figures 5 and 6).

The remaining contributions are much harder to comprehend from the point of view either the nested politics model in particular or the dynamic approach in general, though points of commonality do exist. Buzan's discussion of the English school provides, perhaps, a gateway to the remaining works, in that it focuses on international society – and of necessity, norms, values, and, more broadly, meaning – in the context of

a materialist theory of state and system. Indeed, the role of meaning, which is typically marginalized if not ignored in dynamic modeling (except perhaps in the narrow sense of utility), is central to the social understandings of systemic theorizing on offer from the world culture theorists (Goodman and Jinks, Thomas) and modern systems theorists (Albert, Jaeger).[58]

Clearly, the act of mathematical modeling does not preclude the study of meaning *per se.*[59] The simulated results demonstrate that such a meaning-laden shift as one state's transition from a standard *realpolitik* state to a trading state can be captured handily – though given the arbitrariness of the content of a variable, it should be trivially obvious that mathematical models *could* capture all sorts of things. It is clearly more important to address the question of whether the nested politics model *does* incorporate meaning, and my answer to that question would be that it does, albeit only as an exogenous factor, and sometimes in ways that might not be immediately apparent.

In the empirical test of the model, there is no material element of the system that dictates that states should care about the spread of the distribution of material capabilities, or about domestic political ideology: those are elements of reality that were thought by the elites and publics of the time to have a direct bearing on the probability of interstate conflict, and as such they were prime candidates for regulation. These statements mask a complex relationship involving the assignment of meaning, normative assertions about the value of both war and liberty, and causal beliefs about how the world works – all of which clearly belong in the realm of meaning. By contrast, I argue that the balance of power in the interwar period largely meant the ratio of German power to that of the

remaining Great Powers; thus the meaning of even so material an element of the model necessarily involves the assignment of meaning by the actors involved.

One could also argue, reasonably I think, that changes in meaning would imply changes either in the values of some of the variables (the importance of one dimension of the system vis-à-vis another, say) or in the values of the coefficients relating the variables to one another. Such changes reflect the *effects* of changes in meaning, however, rather than capturing such changes directly or (better yet) helping us to understand them. In the end, although meaning is crucial to the theory in that no specific realization of the model would be possible without it, it acts only in conjunction with the material elements of the model, and variation in meaning is never one of the theory's *explananda.*

Divergence is perhaps inherent in the nature of any field of study, and it may be the case here that social and material understandings of the international system have developed such thoroughly exclusive ontological premises and epistemological practices that they will never completely come together again. This does not mean, however, that that they will ever totally separate either. It is quite significant, I think, that each finds it difficult to dispense with the other completely. Wendt's social theory of international politics embraces a "rump materialism," just as he argues that Waltz's realism rests on an intersubjective notion of anarchy, and just as I have embraced rudimentary elements of meaning. It may be no accident that Albert and I both claim Karl Deutsch as a prominent intellectual influence: Deutsch clearly appreciated the inherent interconnectedness of material and meaning. Despite increasingly substantial differences in premises, methods, and (sometimes, it seems, above all) language, therefore, adherents to the materialist and

the social schools of thought in systemic theorizing may never be rid of one another entirely. I hope not, and I suspect that the field will be richer as a result.

Appendix

Differential Equations

This article utilizes differential equations, which are less daunting than they might appear. A differential equation refers to an equation that captures the change of some variable or variables over time, typically as a function of the values of other variables and/or past values of the variable itself. The statistical complement to a differential equation is a time-series model.

To take the simplest possible example of a differential equation, consider the radioactive decay of an isotope of an element. The isotope loses mass at a rate that is proportional to its present mass, and the proportion is constant over time. If we use Δx to denote "the instantaneous change in variable x"[60] and refer to the mass of the isotope as m and the proportion as α, the isotope's decay can be described by the formula

$$\Delta m = -\alpha m \qquad (2)$$

The behavior of this equation is easy to predict: the mass of the isotope will shrink, but at a decreasing rate, and as the mass dwindles so will the rate of change. If mass were infinitely divisible, the isotope would take forever to become infinitesimally small.

If, in order to complicate things a bit, we decided to add mass to the isotope in order to counteract its decay, and we added that mass at a rate that was constant over time, the equation would change slightly: if we refer to the instantaneous rate at which mass increases as a result of our manipulation as p, we would have

$$\Delta m = -\alpha m + p \qquad (3)$$

Here, too, the result is easy to characterize: if we add more than the isotope loses in a given time period, its mass increases. If we add less than it loses, the isotope's mass

decreases. The isotope's mass reaches a steady state (Δm=0) only when our additions perfectly offset the losses due to decay (that is, $\alpha m=p$).

The differential equations utilized in the model below are more complicated theoretically, but not more complicated mathematically, than this example. For instance, the model predicts no change in the balance of ideology when the impact of the states pushing for the liberalization of Europe is perfectly balanced by the impact of the states pushing in the opposite direction.

The Nested Politics Model

The mathematical form of the nested politics model was derived from the theoretical assumptions described above.[61] In what follows, denote the current state of the world along structural dimension m as as s_m, the level of activity for state i as a_i, realized capabilities for state i as p_i, the salience of structural dimension m to state i as w_{im}, the distribution of ideal points along dimension m among the constituency of state i as c_{im}, and the preference aggregation function of state i as $n_i(\bullet)$.

Without going into too much detail, the argument implies that the state of the world (the balance of power, for example) will not be affected by state i if one of three conditions holds: (1) state i takes no action to alter the state of the world (a_i=0), (2) state i is incapable of altering the state of the world (p_i=0), or (3) state i is utterly disinterested in altering the state of the world (either w_{im}=0, indicating indifference, or $n_i(c_{im})$-s_m=0, indicating satisfaction with the status quo due to the convergence of the state's ideal point

and the state of the system). The most straightforward way of capturing this relationship is a simple multiplicative relationship of the form

$$\mathrm{D}s_m = \mathrm{p}_i \mathrm{w}_{im} a_i [\mathrm{n}_i(c_{im}) - s_m], \quad (4)$$

where Δs_m denotes the change in the state of the world from one time period to the next.[62]

Similarly, the extent to which a state will take action as a result of the state of the world along dimension m depends on how much it cares about that dimension and how far it is from its ideal point. The first quantity is captured by w_{im} and the second by $[\mathrm{n}_i(c_{im})-s_m]^2$. Again, if either is equal to zero, the state will take no action, so a simple multiplicative relationship of the form

$$a_i = \mathrm{w}_{im} [\mathrm{n}_i(c_{im}) - s_m]^2 \quad (5)$$

is the most straightforward interpretation of the theory. Converting to a differential equation to capture the dynamics of the system merely involves subtracting a_i from both sides, so:

$$\mathrm{D}a_i = \mathrm{w}_{im} [\mathrm{n}_i(c_{im}) - s_m]^2 - a_i \quad (6)$$

Finally, to capture the behavior of a system that contains I states and M systemic dimensions, we have to sum the influence of the states on each dimension and sum the influences of the dimensions on each state. Following the partial-adjustment logic laid out above, the former would be captured by the simple sum of the efforts of the states,

$$\mathrm{D}s_m = \sum_{i=1}^{I} \mathrm{p}_i \mathrm{w}_{im} a_i [\mathrm{n}_i(c_{im}) - s_m], \quad (7)$$

and assuming independence across states of the world,[63] the latter gives

$$\mathrm{D}a_i = \sum_{m=1}^{M} \mathrm{w}_{im}[\mathrm{n}_i(c_{im})-s_m]^2 - a_i \qquad (8)$$

References

Almond, Gabriel and Genco, Stephen J. 1977. 'Clouds, Clocks, and the Study of Politics', *World Politics* 29 (4): 489–522

Ashley, Richard 1988. 'On the Relative Worth of Recent Macroeconomic Forecasts', *International Journal of Forecasting* 4: 363–376

Attfield, C.L.F., Demery, D. and Duck, N. W. 1991. *Rational Expectations in Economics*. Cambridge: Blackwell

Axelrod, Robert 1984. *The Evolution of Cooperation*. New York: Basic Books

Axelrod, Robert and Keohane, Robert O. 1986. 'Achieving Cooperation under Anarchy: Strategies and Institutions', in Kenneth A. Oye, *Cooperation Under Anarchy*. Princeton: Princeton University Press: 226–254

Bankes, Steve 1993. 'Exploratory Modeling for Policy Analysis', *Operations Research* 41 (3): 435–449

Bentham, Jeremy 1973. *An Introduction to the Principles of Morals and Legislation*. New York: Hafner Press

Bertalanffy, Ludwig von 1969. *General Systems Theory*. New York: Braziller

Blauberg, Igor Viktorovich, Sadovsky, Vadim Nikolayevich and Yudin, Erik Grigoryevitch 1977. *Teoria System: Filosofskii i Metodologicheskie Problemi*. Moscow: Progress

Bodkin, Ronald G., Klein, Lawrence R. and Marwah, Kanta 1991. *A History of Macroeconometric Modelling*. Vermont: Edward Elgar Publishing Ltd.

Borges, Jorge Luis 1998. *Of Exactitude in Science: In Collected Fictions.* New York: Viking

Brainard, William C. 1967. 'Uncertainty and the Effectiveness of Policy', *The American Economic Review* 57 (2): 411–425

Braumoeller, Bear 2003. 'Causal Complexity and the Study of Politics', *Political Analysis* 11 (3): 209–233

Braumoeller, Bear 2005. *Systemic Politics: The Great Powers in General (Dis-)Equilibrium*. Paper presented at the Mershon Center at the Ohio State University, May 20, 2005

Braumoeller, Bear 2006a. *Great Power Politics and the Dynamics of the International System*. Unpublished manuscript, Harvard University

Braumoeller, Bear 2006b. *Systemic Politics, Spirals, and Deterrence in 19th Century Europe*. Unpublished manuscript, Harvard University

Bremer, Stuart 1977. *Simulated Worlds: A Computer Model of National Decision-Making*. Princeton: Princeton University Press

Bremer, Stuart 1987. *The GLOBUS Model: Computer Simulation of Worldwide Political and Economic Developments*. Boulder: Westview Press

Bremer, Stuart and Michael Mihalka 1977. 'Machiavelli in Machina: Or Politics Among Hexagons', in Deutsch, Karl W., Fritsch, Bruno, Jaguaribe, Helio and Markovits, Andrei S., *Problems of World Modeling: Political and Social Implications*. Cambridge: Ballinger Publishing Company

Bueno de Mesquita, Bruce and Lalman, David 1988. 'Empirical Support for Systemic and Dyadic Explanations of International Conflict', *World Politics* 41 (1): 1–20

Bull, Hedley and Watson, Adam (eds.) 1984. *The Expansion of International Society*. Oxford: Oxford University Press

Buzan, Barry 1993. 'From International System to International Society: Structural Realism and Regime Theory Meet the English School', *International Organization* 47 (3): 327–352

Buzan, Barry, Jones, Charles and Little, Richard 1993. *The Logic of Anarchy: Neorealism to Structural Realism*. New York: Columbia University Press

Carlsnaes, Walter 1992. 'The Agency-Structure Problem in Foreign Policy Analysis', *International Studies Quarterly* 36 (3): 245–270

Cederman, Lars-Erik 1997. *Emergent Actors in World Politics*. Princeton: Princeton University Press

Cederman, Lars-Erik 2001. 'Agent-Based Modeling in Political Science', *The Political Methodologist* 10 (1), 16–22

Chong, Dennis 2000. *Rational Lives: Norms and Values in Politics and Society*. Chicago: University of Chicago Press

Choucri, Nazli and North, Robert C. 1975. *Nations in Conflict: National Growth and International Violence*. San Francisco: W.H. Freeman

Cole, H.S.D., Freeman, Christopher, Jahoda, Marie and Pavitt, K.L.R. 1973. *Models of Doom: A Critique of the Limits of Growth.* New York: Universe Books

Craig, Gordon A. and George, Alexander L. 1983. *Force and Statecraft: Diplomatic Problems of Our Time*. New York: Oxford University Press

Cusack, Thomas R. and Stoll, Richard 1990. *Exploring Realpolitik: Probing International Relations Theory with Computer Simulation*. Boulder: Lynne Rienner

deMarchi, Scott, Gelpi, Christopher and Grynaviski, Jeffrey D. 2004. 'Untangling Neural Nets', *American Political Science Review* 98 (2): 371–378

Deutsch, Karl W. 1966. *The Nerves of Government: Models of Political Communication and Control*. New York: The Free Press

Deutsch, Karl W. 1978. *The Analysis of International Relations*. Englewood Cliffs: Prentice-Hall

Deutsch, Karl W. and Singer, J. David 1964. 'Multipolar Power Systems and International Stability', *World Politics* 16: 390–406

Enelow, James M. and Hinich, Melvin J. 1984. *The Spatial Theory of Voting: An Introduction*. Cambridge: Cambridge University Press

Evans, Robert 1997. 'Soothsaying or Science?: Falsification, Uncertainty, and Social Change in Macroeconometric Modelling', *Social Studies of Science* 27 (3): 395–438.

Fildes, Robert and Stekler, Herman 2002. 'The State of Macroeconomic Forecasting', *Journal of Macroeconomics* 24: 435–468

Gholz, Eugene, Press, Daryl G. and Sapolsky, Harvey M. 1997. 'Come Home, America: The Strategy of Restraint in the Face of Temptation', *International Security* 21 (4): 5–48

Giddens, Anthony 1979. *Central Problems in Social Theory: Action, Structure, and the Contradiction in Social Analysis*. Berkeley: University of California Press

Gillespie, John V., Zinnes, Dina A., Tahim, G.S., Schrodt, Philip A. and Rubison, Michael 1977. 'An Optimal Control Model of Arms Races', *American Political Science Review* 71 (1): 226–244

Gilpin, Robert 1981. *War and Change in World Politics*. Cambridge: Cambridge University Press

Guetzkow, Harold and Valadez, Joseph J. (eds.) 1981. *Simulated International Processes: Theories and Research in Global Modeling*. Beverly Hills: Sage Publications

Haas, Ernst B. 1953. 'The Balance of Power: Prescription, Concept, or Propaganda?', *World Politics* 5: 442–477

Hall, Stephen 1995. 'Macroeconomics and a Bit More Reality', The Economic Journal 105 (431): 974–988

Harty, Martha and Modell, John 1991. 'The First Conflict Resolution Movement, 1956-1971: An Attempt to Institutionalize Applied Interdisciplinary Social Science', *Journal of Conflict Resolution* 35 (4): 720–758

Hickman, Bert G. 1991. 'Project LINK and Multi-Country Modelling', in Bodkin, Ronald G., Klein, Lawrence R. and Marwah, Kanta (eds.), *A History of Macroeconometric Modelling*. Vermont: Edward Elgar Publishing Ltd.: 482–506

Hinsley, F. H. 1963. *Power and the Pursuit of Peace: Theory and Practice in the History of Relations between States*. Cambridge: Cambridge University Press

Jervis, Robert 1997. *System Effects: Complexity in Political and Social Life*. Princeton: Princeton University Press

Kaplan, Morton 1957. *System and Process in International Politics*. New York: John Wiley and Sons

Keeney, Ralph L. and Raiffa, Howard 1993. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. Cambridge: Cambridge University Press

Kennedy, Peter 1985. *A Guide to Econometrics (2nd ed.)*. Cambridge: MIT Press

Keohane, Robert 1984. *After Hegemony: Cooperation and Discord in the World Political Economy*. Princeton: Princeton University Press

Keohane, Robert 1989. *International Institutions and State Power*. Boulder: Westview Press

Keohane, Robert O. 1983. 'The Demand for International Regimes', in Krasner, Stephen D. (ed.), *International Regimes*. Ithaca: Cornell University Press: 141–171

Kissinger, Henry 1957. *A World Restored*. London: Weidenfeld and Nicolson

Kissinger, Henry 1994. *Diplomacy*. New York: Simon and Schuster

Klotz, Audie 1995. 'Norms reconstituting interests: global racial equality and U.S. sanctions against South Africa', *International Organization* 49(3): 451–478

Knorr, Klaus and Verba, Sidney (eds.) 1961. *The International System: Theoretical Essays.* Princeton: Princeton University Press

Krasner, Stephen D. (ed.) 1983. *International Regimes.* Ithaca: Cornell University Press

Kratochwil, Friedrich 1982. 'On the Notion of "Interest" in International Relations', *International Organization* 36(1): 1–30

Li, Richard P. Y. and Thompson, William R. 1978. 'The Stochastic Process of Alliance Formation Behavior', *American Political Science Review* 72(4): 1288–1303

McClelland, Charles A. 1966. *Theory and the International System*. New York: The Macmillan Company

Meadows, Donella H., Meadows, Dennis L., Randers, Jorgen and Behrens, William W. 1972. *The Limits to Growth*. New York: Potomac Associates

Mearsheimer, John J. 2001. *The Tragedy of Great Power Politics*. New York: W. W. Norton & Co.

Morgenthau, Hans J. 1948. *Politics Among Nations: The Struggle for Power and Peace*. New York: Alfred A. Knopf

Mueller, Dennis C. 1989. *Public Choice II*. Cambridge: Cambridge University Press

Muncaster, Robert G. and Zinnes, Dina A. 1983. 'A Model of Inter-Nation Hostility Dynamics and War', *Conflict Management and Peace Science* 6(2): 19–37

Neely, Christopher J. and Sarno, Lucio 2002. 'How Well do Monetary Fundamentals Forecast Exchange Rates?', *Federal Reserve Bank of St. Louis Review* 84(5): 51–74

Nooruddin, Irfan 2002. 'Modeling Selection Bias in Studies of Sanctions Efficacy', *International Interactions* 28(1): 57–74

Organski, A.F.K. and Kugler, Jacek 1980. *The War Ledger*. Chicago: University of Chicago Press

Oye, Kenneth (ed.) 1986. *Cooperation under Anarchy.* Princeton: Princeton University Press

Pepinsky, Thomas B. 2005. 'From Agents to Outcomes: Simulation in International Relations', *European Journal of International Relations* 11(3): 367–394

Persson, Torsten and Tabellini, Guido 2002. P*olitical Economics: Explaining Economic Policy*. Cambridge: MIT Press

Pollins, Brian M. 1996. 'Global Political Order, Economic Change, and Armed Conflict: Coevolving Systems and the Use of Force', *American Political Science Review* 90(1): 103–117

Pollins, Brian M. and Schweller, Randall L. 1999. 'Linking the Levels: The Long Wave and Shifts in U.S. Foreign Policy, 1790-1993', *American Journal of Political Science* 43(2): 431–464

Resnick, Mitchel 1994. *Turtles, Termites, and Traffic Jams*. Cambridge: MIT Press

Richardson, Lewis F. 1960. *Statistics of Deadly Quarrels*. Chicago: Quadrangle Books

Rosecrance, Richard 1986. *The Rise of the Trading State: Commerce and Conquest in the Modern World*. New York: Basic Books

Rosecrance, Richard N. 1963. *Action and Reaction in World Politics*. Boston: Little, Brown and Co.

Saperstein, Alvin M 1999. *Dynamical Modeling of the Onset of War*. River Edge: World Scientific

Sargent, Thomas J. 1978. 'Estimation of Dynamic Labor Demand Schedulesunder Rational Expectations', *The Journal of Political Economy* 86(6): 1009–1044

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

Schroeder, Paul W. 1994. *The Transformation of European Politics*. Oxford: Clarendon Press

Schweller, Randall L. 1998. *Deadly Imbalances: Tripolarity and Hitler's Strategy of World Conquest*. New York: Columbia University Press

Sims, Christopher A. 1980. 'Macroeconomics and Reality', *Econometrica* 48(1): 1–48

Singer, J. David, Bremer, Stuart and Stuckey, John 1972. 'Capability Distribution, Uncertainty, and Major Power War, 1820-1965', in Russett, Bruce M. (ed.), *Peace, War, and Numbers*. Beverly Hills: Sage Publications

Starr, Harvey 1978. '"Opportunity" and "Willingness" as Ordering Concepts in the Study of War', *International Interactions* 4(4): 363–387

Stephens, Jerone 1972. 'An Appraisal of Some System Approaches in the Study of International Systems', *International Studies Quarterly* 16(3): 321–349

Turchin, Peter 2003. *Historical Dynamics: Why States Rise and Fall*. Princeton, NJ: Princeton University Press

Waltz, Kenneth N. 1979. *Theory of International Politics*. New York: Random House

Weltman, John J. 1973. *Systems Theory in International Relations: A Study in Metaphoric Hypertrophy*. Lexington, MA: D. C. Heath & Co

Wendt, Alexander 1999. *Social Theory of International Politics*. Cambridge: Cambridge University Press

Wolfson, Murray, Puri, Anil and Martelli, Mario 1992. 'The Nonlinear Dynamics of International Conflict' *Journal of Conflict Resolution* 36(1): 119–149

Zaller, John 1992. *The Nature and Origins of Mass Opinion*. New York: Cambridge University Press

Zinnes, Dina A. and Muncaster, Robert G. 1988. 'The War Propensity of International Systems', *Synthese* 76(2): 307–331

Notes:

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[1]As the concept of a system will be very important to this endeavor, it merits explicit definition. Hedley Bull and Adam Watson define a system as a situation in which "the behaviour of each actor is a necessary factor in the calculations of the others." (1984, 1) Anthony Giddens, quoting Amitai Etzioni, defines a social system as "a relationship in which changes in one or more component parts initiate changes in other component parts, and these changes, in turn, produce changes in the parts in which the original changes occurred." (1979, 73) The system of states, or at least that of Great Powers, surely counts as a system by these criteria.

[2]Quite a few other characteristics, such as nonlinearity, equifinality, and the omnipresence of unintended results, have been attributed to systems; for a thorough discussion see Jervis (1997, ch. 2), and for a brief summary see, for example, Schweller (1998, 7-8). I do not consider them to be especially compelling justifications for taking a systemic approach, however, for two reasons: one, they are hardly unique to systems, so systems don't raise problems in those regards that haven't already been raised elsewhere,

and two, they have been dealt with in a much more satisfactory way already than have the analytical problems outlined above.

[3]See e.g. Saperstein (1999).

[4]Bertalanffy (1969) is the seminal discussion.

[5]Richardson(1960).

[6]See Stephens (1972) for a discussion of the American literature and Blauberg et al. (1977) for a Soviet assessment. The Soviet view is noteworthy in that dialectical materialism would seem, on the surface, to be particularly amenable to a systems approach; the authors' assessment of its promise is qualified at best. McClelland (1966) is an interesting early discussion of general systems theory and international relations research; see also Harty and Modell (1991) for a retrospective analysis.

[7]See e.g. Pavitt, Cole et al. (1973).

[8]See Gillespie et al. (1977), Li and Thompson (1978), Muncaster and Zinnes (1983), and Wolfson et al. (1992) for examples.

[9]There is one exception to this generalization: Thomas Schelling's "neighborhood model" (1978) demonstrated that surprising conclusions could be derived from ABMs using nothing but pennies, dimes, and a chessboard.

[10]For a thorough review of recent literature see Cederman (2001).

[11]Waltz would undoubtedly argue against such an assertion; he refers to his predecessors collectively as "students of international politics who claim to follow a systems approach" (Waltz 1979).

[12]Other prominent works that could be cited as examples of the latter include Jervis (1997), Knorr and Verba (1961), Rosecrance (1963), Deutsch and Singer (1964), Keohane (1984), Buzan et al. (1993), and Wendt (1999).

[13]Quite a few theories that currently pass as systemic fail to establish reciprocal theoretical linkages between the structure of the system and the states that comprise it. Gilpin (1981) and Organski and Kugler (1980) are illustrative: the former explains the sources of economic boom and stagnation in individual states, setting the stage nicely for an understanding of systemic change, while the latter describes how state preferences are translated into action *given* an existing distribution of power in the system. Moreover, hypothesized linkages between the two levels typically take little account of any of the detailed theoretical knowledge that has been gleaned about either (for an exception, see Pollins and Schweller 1999). It is also not uncommon to see a theory described as "systemic" simply because it incorporates variables from the structural level (e.g., Bueno de Mesquita and Lalman 1988).

[14]Deutsch and Singer (1964), Deutsch (1966); see also Deutsch (1978).

[15]Singer et al. (1972); Bremer (1977), Bremer and Mihalka (1977). Bremer and Mihalka, for example, conclude that "if political entities act according to the dictates of 'realism,' the consequence for the vast majority is extinction, not survival" (326).

[16]Wendt (1999) and Mearsheimer (2001), respectively.

[17]Resnick (1994).

[18]Such works include Cusack and Stoll (1990), Wolfson et al. (1992), and Cederman (1997).

[19]I am indebted to David Lake (private communication) for the suggestion that I explore general equilibrium theory as a body of work relevant to my own thinking about the international system.
[20]See Bodkin et al. (1991) for a review.
[21]To be clear, innocence here connotes the absence of knowledge or expectations, not the absence of guilt.
[22]Carlsnaes (1992) makes this point in detail. To summarize, "as long as actions are explained with reference to structure, or vice versa, the independent variable in each case remains unavailable for problematization in its own right," and the solution to the problem involves solving the problem of "how to make analytically operational the core assumption that both agents and social structures interact reciprocally in determining the foreign policy behavior of sovereign states" (p. 250).
[23]It is worth noting that Pepinsky's (2005) critique of agent-based models in international relations—that agents, environments, and relations among them are taken to be ontologically prior to emergent properties, and that international relations theory does not admit of sufficient consensus to warrant such strong prior assumptions—applies to macroeconometric models as well. Indeed, the estimation portion of the exercise might seem even more problematic (because it is more efficient) than the agent-based modeler's ability to tinker with the parameters of the model until something approximating reality emerges. Two responses are in order. First, the critique applies to all deductive theorizing in IR, not just model building. Second, the force of the critique can be blunted if the model is built in such a way that existing theories can be expressed as special cases of a more general model, as is the case with the nested politics model outlined below.
[24]Evans (1997). Briefly, three responses seem reasonable: one, that the ratio of stochastic to systematic variation is variable-specific, and some variables are more predictable than others; two, that contemporary research can never actually ascertain this ratio, as the possibility of explaining additional variance always remains; and three, that even if the critique holds, macroeconometric modeling still captures the systematic part of behavior, and nothing save dumb luck would capture the rest. (To put it another way, what is the alternative?)
[25]Hall (1995, 975, 983).
[26]Hickman (1991) traces the development of the multi-national Project LINK from its early days, when it comprised 1,500 equations, to 1985, when it was made up of about 20,000 (!)
[27]In the first of two conferences convened to discuss the articles in this collection, William Thompson suggested that there would be some value in modeling Waltz's or Gilpin's theories of international politics. Perhaps predictably, I prefer my own. Nevertheless, I agree: one could surely write down Waltz's theory of international politics as a special case of the model described here, without doing much violence to either. Indeed, in the larger manuscript I do so and demonstrate that Waltz's conclusions regarding the tendency of balances to form cannot, strictly speaking, be derived from a set of premises that include states as "unitary actors who, at a minimum, seek their own preservation and, at a maximum, drive for universal domination" (Waltz 1979). Gilpin's theory would be a bit more difficult and would have to endogenize capabilities by

including a model of the state's economic growth and stagnation—an enterprise which actual macroeconomists have found quite daunting.

[28]For a considerably more detailed explication see Braumoeller (2006a).

[29]The assertion that preferences follow from interests is widely but not universally accepted. Kratochwil (1982, 5-6), for example, argues that "we can think of cases in which it makes sense to distinguish carefully something wanted or desired—like sitting down in a snowstorm due to exhaustion—from the interest involved—not doing so because of the danger of freezing to death." It seems to me that there are actually two interests here (rest and survival) and two preferences that stem from them (sitting and not), and that the latter simply outweighs the former. See Keeney and Raiffa (1993) for a discussion of multiple preferences that would accommodate such an example.

[30]Following the conventions of expected utility theory, disutility is actually a function of the square of the distance between the ideal point and the existing state of the world.

[31]This is a very "vanilla" probabilistic voting model, meant to apply to a wide range of states. Quite a few additional nuances, such as interest groups, ideology of voters, etc., have been added to explain the features of different electoral systems (see Persson and Tabellini 2002 for examples), but the basic model seems most well-suited to describing features common to political systems in general.

[32]As it happens, this position is the one that is optimal for the entire community—at least by the standards of Jeremy Bentham, who wrote in Chapter 1 of *Principles of Morals and Legislation* (1823) that "the interest of the community then is...the sum of the interests of the several members who compose it."

[33]Mueller (1989, 199-202).

[34]John Zaller (1992) has developed a model of opinion formation in which elites are drawn from subpopulations with different ideological predispositions, specialize in policy formulation, and send "messages" in the form of policy statements back to the public via the media. These messages, when received, resonate most strongly in citizens with sympathetic predispositions. Voter opinion is therefore seen as a function of attentiveness, predispositions, and the strength of the message (as well as of any events in the international arena that happen to make one issue or another particularly salient). To win elections, candidates must adopt clusters of policies that resonate as strongly as possible with the subpopulation that constitutes their base of support. These themes are elaborated throughout the book and are neatly captured in Zaller's "Parable of Purple Land" (pp. 311-312). The model is essentially a simple version of a spatial theory of voting in which the population's preferences in issue-space are bimodal and candidates are drawn to the modes. A vast literature exists on this subject; for a review and an excellent example, see Enelow and Hinich (1984).

[35]Examples in the American context abound; for a recent example see Gholz et al. (1997).

[36]Latent and realized capabilities must be distinguished from one another both in order to avoid tautology and because they play different roles in the theory: realized capabilities determine the impact of a state's action on the status of the international system, whereas latent capabilities, which capture the state's long-run or potential strength, are more relevant to its place in the international power hierarchy.

[37]It would be reasonable to wonder why one would not expect leaders to act proactively rather than retroactively, in accordance with the rational expectations tradition; see

Attfield et al. (1991). In brief, the existence of substantial adjustment costs and uncertainty about the model's parameters will push actors toward retroactive rather than proactive adjustment (Sargent 1978, Brainard 1967).

[38]A reasonable transition rule for two states *i* and *j*, which I utilize in the above simulation, would then be:

$$\Delta f_{cip} = \sum_{q} (1-\frac{f_{cip}}{f_{cjp}})-(1-\frac{f_{ciq}}{f_{cjq}}) \quad (1)$$

[39]In this abstract example, these resources can be defined in a variety of ways; my own preference is to think of them as representing exclusive trade agreements and latent power resources, respectively.

[40]For the sake of illustration it is assumed that their ideal points along those dimensions are already the same; permitting them to vary and including them in the process of socialization as well would simply draw out the process of convergence. The results were produced by a model that assumes fairly intense socialization processes. The degree of intensity could be modified, but this is merely an illustration, and the time units are arbitrary in any event.

[41]See Braumoeller (2006a).

[42]Hinsley (1963, 197).

[43]Such regulation is not uncommon and varies widely in degree of complexity, from the evolution of cooperative norms (Axelrod 1984, Oye 1986) to what international relations specialists call "regimes" (Keohane 1983, 1984; Krasner 1983) to formal institutions (Axelrod and Keohane 1986, Keohane 1989).

[44]The labels are my own. For a lucid dissemination on the general subject of the meaning of the balance of power see Haas 1953. I have no intention of delving further into definitional intricacies, but the interested reader will find food for thought in Morgenthau (1948, 132-133), Rosecrance (1963, ch. 11), Kissinger (1957, 146-147), Waltz (1979, 117-123, 163-170), and Craig and George (1983, ch. 3).

[45]See Starr (1978) for a discussion of the breadth of the applicability of these two concepts.

[46]See Braumoeller (2005, 34-41, 45), at http://www.people.fas.harvard.edu/~bfbraum.

[47]Following the theoretical model, the dependent variables were measured in differences, which eliminated autocorrelative trends as well as alleviating issues of nonstationarity.

[48]At the time of this writing these results are still being analyzed and should therefore be considered preliminary; nevertheless, as the discovery of (for example) substantial break-points in the coefficients should only improve the predictions, they likely constitute a conservative estimate of the model's predictive ability.

[49]The exception is Prussia, which, due to lack of variance in the early series, had to be estimated from 1850 on.

[50]Then again, neither did the Austrians, so perhaps the model should not be judged too harshly.

[51]Cederman also argues that agent-based models go "beyond a narrow focus on equilibria by explicitly considering non-equilibrium processes." While it is true that some equation-based models, especially those in the rational expectations school, focus on equilibria, many do not: in the model outlined above, for example, states spend most if not all of their time out of equilibrium.

[52]It should be noted that randomness need not be a part of an agent-based model at all. Conway's original game of *Life,* for example, consisted of agents that behave in an entirely deterministic way but produce outcomes that seem somewhat random, at least at first.

[53]While the existence of too much unexplained variance is obviously a problem for an equation-based modeler, the existence of too little unexplained variance, one might argue, would be a problem for those humans who like to believe in free will; therefore, describing unexplained variance as a "nuisance," as is often done in econometrics texts, is not entirely accurate.

[54]Discussion of these concepts can be found in most good econometrics texts; see e.g. Kennedy (1985). To illustrate: Imagine two separate econometric models, one explaining when international sanctions are imposed and another explaining whether or not they succeed in their goals. States become targets of sanctions in the first model because of both systematic factors (variables in the equation) and unexplained recalcitrance (positive error). Because recalcitrant states from the first equation are likely to remain recalcitrant in the second equation—that is, because the errors are correlated—, it is unlikely that the error term in the second equation will have a mean of zero, and inferences about the determinants of sanctions' success drawn from the second model, in isolation, are likely to be biased. See Nooruddin (2002) for an examination of precisely this issue.

[55]For an attempt to extend the above model to account for Great Power conflict behavior, see Braumoeller (2006b).

[56]Readers interested in a direct and thought-provoking discussion of the similarities and differences between the two schools are advised to seek out an exchange between these two scholars in *International Studies Quarterly,* volume 27, #3. For an empirical investigation of the relationship between structure and war that supports a fusion of the two schools, see Pollins (1996).

[57]To some extent, one of Chase-Dunn's recent coauthors makes the opposite tradeoff, sacrificing concreteness of data for historical scope: Turchin (2003) is a remarkably ambitious and wide-ranging exploration of world history, using differential equations as a guide. Compared to Choucri and North, the most prominent differences would be a higher ratio of deductive theorizing to statistical testing and considerably greater historical range.

[58]I am indebted to Alex Wendt for formulating this distinction in the first conference devoted to this collection of articles.

[59]For an excellent example, see Chong (2000).

[60]This can also be denoted by $\dot{x}$ or $\frac{\partial x}{\partial t}$.

[61]In the comments mentioned in footnote 0.4 above, it became clear that I had conveyed the impression that the theory had been constructed to fit the formal model. Nothing could be farther from the truth; in fact, I have devoted considerable effort to promoting the derivation of formal specifications from theory rather than vice-versa (see, for instance, Braumoeller 2003) and consider the derivation of theories from convenient mathematical or statistical specifications to be one of the worst problems plaguing formal and statistical IR. Indeed, given the requirements of estimation, the mathematical form taken by the nested politics theory is far from convenient!

[62]For any variable x, Δx is defined as x_{t+1}-x_t; if there is no change from time t to time t+1, then Δx=0.

[63]This assumption could be questioned. Taking action to alter the balance of power might somewhat reduce the amount of activity necessary to alter the balance of ideology. It might just as well be true in other cases, however, that acting to alter the balance of power makes it *harder* to alter the balance of ideology, because of the resistance engendered by the former act. Therefore, although an individual case could well demonstrate a positive or negative relationship, a null relationship seems at least plausible in the aggregate (and even, given that this is not a relationship of great theoretical interest, desirable).