Developing Non-Equilibrium Theory of World Politics*

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Today's IR theorizing appears curiously static and detached from the revolutionary changes that the world is presently undergoing. This memo argues that this theoretical discrepancy will not be overcome without a radical revision of IR theory's fundamental assumptions. In particular, I propose a broadening of the research agenda from almost exclusive reliance on microeconomic analogies and methods to the full incorporation of an alternative, more sociological research orientation based on non-equilibrium physics and complexity theory.

My argument unfolds in three steps: first I will show why a comprehensive account of change in world politics requires theorizing macro processes. The second step illustrates that most current theories are both too myopic and static to explore such processes. Third, I suggest that recent advances in non-equilibrium physics and complexity theory may help us close the system-theoretical deficit by providing fertile concepts, analogies, and modeling cues. I conclude with a brief section illustration potential applications to world politics.

Why macro theory is needed to explain change in world politics

To conceptualize different types of political transformations, it may be useful to introduce Gilpin's (1981) classical three-fold classification of change in world politics:

- *Systems change* is the most fundamental type because it concerns the very nature of the units, i.e. the actor types;
- *Systemic change* is the next level and it relates primarily to the coming and going of specific units, as well as alterations of their outer boundaries;
- *Process change* is the most superficial type since it merely relates to the dynamics and behavioral interactions among given units, such as cooperation, conflict, and alliance formation, or the units' properties, such as regime change.

Each of Gilpin's levels of change can enter a research design in two ways: either the *effects of exogenous change* are investigated through "comparative statics" analysis, or change is *endogenized as an emergent phenomenon* in its own right. While the analyst manipulates the changing factors of the system in the former case, in the latter the system is expected to generate change without external manipulation.

Combining the three levels of change and the two theoretical roles creates a 3 x 2 table (see Table 1). Each box contains examples illustrating the mode of analysis in question. For example, cell 1 captures studies that trace the exogenous effects of process change. Much of the quantitative literature on the democratic peace exemplifies this type of research. Likewise, the role of the offense-defense balance is often limited to studying the impact of technology on interstate relations. Once process change becomes endogenous, however, the attention shifts to the emergence of behavioral and attitudinal patterns among given units, as illustrated by Axelrod's evolutionary theory of cooperation or

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Deutsch's security communities (see cell 2). The next level of change introduces fluctuations in specific actors and actor constellations. Again, some theorists prefer to regard change as an exogenous factor while investigating its repercussions (see cell 3). Other students of systemic change endogenize the phenomenon in an attempt to explain the fortunes of great powers (see cell 4). Finally, systems change explicitly implies shifts in unit types. Again, whereas some analysts content themselves with studies of the consequences of such transformations (cell 5), others strive to explain the emergence of novel organizational forms, be they they territorial sovereignty or supranational integration (cell 6).

Table 1. A classification of change in IR theory drawing on Gilpin (1981)

	Theoretical role of change:	
Type of change:	Effects of exogenous change	Emergence of endogenous change
Systems change	5. Effects of nationalism: *Clausewitz*, *Howard* Effects of transnationalism: *Keohane & Nye*	6. Emergence of the sovereign, territorial state: *Spruyt*, *Tilly* Emergence of supranational integration: *Deutsch*, *Haas*
Systemic change	3. Effects of polarity and hegemonic stability: *Waltz*, Keohane Effects of multi-ethnic state collapse: *Posen*, *Fearon*	4. Emergence of great powers: *Gilpin*, *Kennedy*, *Goldstein* Emergence of polarity: *Cederman*
Process change	1. Effects of regime type: *Doyle*, *Russett* Effects of offense/defense: *Snyder*, *Van Evera*, *Posen*	2. Emergence of cooperation: *Axelrod* Emergence of trust and norms: *Deutsch*, *Bull*

Given this taxonomy, what can be said about today's international system? At first glance, the end of the Cold War and the collapse of the Soviet empire appear to involve primarily systemic change because the most visible developments involved turnover of territorial states. Yet, it could be argued that the sources of collapse lie deeper, because they certainly involved the increasing role of nationalist mobilization thus rendering cell 5 relevant. To the extent that the changes are put in a perspective going all the way back to the French Revolution, theorizing would have to consider cell 6 as well (see Cederman 2002c).

In the wake of September 11, terrorism is often thought to have transformed world politics through organizational innovations partly driven by new communications technologies, such as decentralized networks and large-scale, civilizational mobilization patterns (cf. Huntington). Whether the goal is to study the effects of these potential changes (cell 5) or their very origins (cell 6), the focus is clearly moving from process change to more profound types of transformations. Likewise, in the eyes of many theorists, European integration represents a similar epochal shift to a new (*sui generis*) type of unit (Jachtenfuchs and Kohler-Koch 1996) that symbolizes a new level of deterritorialization (Ruggie 1993).

By contrast, change during the Cold War centered on process change, at least with respect to the core relationship between the superpowers. Therefore, it is natural that IR theory came to center on cells 1 and 2 (with studies of European integration and nation-building in the Third World being the main exceptions).

While process change often results from on-going systemic and/or systems change, it seems clear that the end of the Cold War has rendered the latter, more profound types of transformations more central to an understanding of world politics. This raises the question of how IR theory has developed in response to this real-world trend.

Current microeconomic theories are too myopic and static

This section attempts to demonstrate that, ironically enough, IR theory is currently moving in the opposite direction, namely toward an almost exclusive focus on exogenous process change. This is to large extent due to the increasing influence of microeconomics on political science. First, this theoretical trend became palpable in IR through analogical reasoning used by neorealist scholars (e.g. Waltz 1979). More recently, the growing impact of methods used by political economists, such as game theory and econometrics, has accentuated the systemic-theoretic deficit. These conceptual developments tend to hamper the formulation of dynamic macro theories because the micro-economic research program is analytically oriented, equilibrium-based, nomological, and actor-reifying:

Analytical approach. Rationalist scholars subscribe to an analytical, rather than to a synthetic, approach. The analyst attempts to cut up social reality into convenient "boxes," which are then analyzed separately. According to this "partial equilibrium perspective," the hope is that these findings are going to add up unproblematically: "The methodological bet in the strategic-choice approach is that interactions do aggregate in an orderly fashion" (Lake and Powell 1999, p. 17). This logic implies that the researchers can proceed by isolating single dimensions analytically and tease out their effects *ceteris paribus* (Ibid. p. 32). But such an analysis requires that the bulk of the conditions be held constant. Lake and Powell explicitly assume that "the features of the strategic setting can usefully be treated as fixed, at least in the short term or for a single interaction" (p. 33). In fact, the insistence on the *ceteris paribus* clause recurs in most IR applications of statistics (e.g. King, Keohane, and Verba 1994). In their quest for degrees of freedom, quantitative analysts often divide the sample into smaller parts, thus fragmenting historical processes. In addition, they typically assume their observations to be independent (or interdependent in unvarying, simple ways) (see critique in Abbott 1988).

Equilibrium-based theory. The analytical goal of the microeconomic approaches is to derive an equilibrium that can be used for empirical validation. Thus, rational-choice theory assumes history to be "efficient" in the sense proposed by March and Olsen (1998, p. 314): "The presumption is that political bargains adjust quickly and in a necessary way to exogenous changes, and changes in orders are explained as stemming from exogenous changes in interests and resources." This fits perfectly as a description of Waltzian neorealism, which stresses negative feedback and homeostatic balance-of-power equilibria. In more explicit applications of rationalistic modeling, the situation is much the same, because here dynamics enter the picture only implicitly, if at all: "The concept of equilibrium in inherently static since it is defined as the absence of any tendency of change. And the standard way to model 'dynamic' choice is by redefining it as a static choice of an optimal strategy for all time, typically under an assumption of stable preferences" (Snidal 2002, p. 82). Again, the stress is on exogenous variation, for according to Snidal, "change is usually introduced through comparative static analysis of how the equilibrium shifts in response to exogenous change. The actual dynamic process and time path are not described, but bracketed under the assumption that actors adjust to a new equilibrium as it emerges"(p. 53).[1]

Nomological inference. IR scholars who draw on economics typically import meta-theoretical conceptions that are popular with economists. In particular, adherence to microeconomics usually means implicit acceptance of extreme versions of positivism and nomological ideals of causation. For one, it is often suggested that causal explanation entails the discovery of universally applicable and unchanging "covering laws." The role of modeling according to most rational-choice scholars, then, is to generate generalizeable hypotheses that can be tested in a large number of cases (see Lake and Powell 1998, p. 16; Green and Shapiro 1994). In the last decade or so, several rational-choice modelers have applied a combination of game theory and statistics to IR topics (e.g. Bueno de Mesquita and Lalman 1992). Yet, the insistence on nomological causation makes it very tricky to trace macro-level changes due to need for large numbers of cases. For sure, not all rational-choice scholars regard modeling as a mere generator of generalizeable knowledge. Some view the search for "mechanisms" (Elster 1989), or the elaboration of "analytical narratives" (Bates et al. 1998) as an equally, or perhaps more, realistic goal. Yet, the methodological "standard operating procedures" of microeconomic analysis continues to gain strength in IR.

Actor reification. Without exception, rational-choice theory reifies the actors of strategic situations. Thus, individuals or collective actors are all assumed to enter the analysis as pre-socially given entities. Moreover, their very identities are supposed to remain intact throughout the course of game. This especially pertains to actors' boundaries constituting their corporate identities (Wendt 1999). Consequently, it becomes very difficult to trace, let alone explain, entity processes such as merger and division. The situation becomes even more tricky if formal modeling is combined with statistics, because the case-based logic of quantitative data set are notoriously hard to marry with such fundamental transformations (Abbott 1988). To some extent, evolutionary theory can compensate for these difficulties by at least handling birth-and-death processes, but traditionally this logic has been used in microeconomic analysis as a justification for demanding rationality assumptions (Friedman 1953) or for particular equilibria, as in evolutionary game theory (Binmore 1990). These are serious limitations because both endogenous systemic and systems change *by definition* feature existential unit processes but also boundary transformations.

Together, the analytical methodology, the equilibrium-centered perspective, the nomological epistemology, and actor reification conspire against attempts to put micro-economically inspired IR theory on a dynamic footing. Ironically enough, as the real world increasingly exhibits macro-historical change, the discipline appears to be moving in the opposite direction, thus opening up an ever widening system-theoretic deficit. It is not inconceivable that the perceived lack of policy relevance and tendencies toward theoretical retrofitting afflicting contemporary IR could be at least partly traced to this conceptual discrepancy.

Some IR scholars have not only noticed this lacuna, but have also produced book-length attempts to develop a systemic response. As suggested by the title of his book, Jervis (1997) discusses several kinds of systems effects together with a large number of

[1] To some extent, evolutionary game theory has brought in diachronic considerations, but these are mostly considered as a way to select among multiple Nash equilibria rather than to trace historical trajectories (cf. Kahler 1998). The main shortcoming remains the failure to account for transitions between equilibria.

historical illustrations, focusing especially on positive feedback and historical contingency. Yet, as admitted by the author, the study falls short of producing a coherent theory capable of tying together the mechanisms and historical observations. Paradoxically enough, Jervis appears to regard Waltz (1979) as the best systemic theory of IR that can be found, despite Waltz' explicit commitment to negative feedback.

Another scholar who explicitly uses Waltz as a theoretical starting point is Wendt (1999). His book also attempts to develop holistic theory but is more ambitious. Like Jervis, Wendt realizes the need to embrace process theory, but unfortunately, his attempt also fails to offer a full-fledged macro-theoretic alternative due to its exclusive focus on micro-level mechanisms derived from symbolic interactionism. As Wendt admits toward the end of the book, his theory "focused entirely on the logic of identity-formation at the micro-level, which does not in itself explain structural change at the *macro-level*" (Wendt 1999, p. 365). In this sense, Wendt's approach is analytical rather than holistic. Moreover, Wendt's essentialist theory of the state hard-wires actor boundaries and treats states as pre-social entities that do not change once they have entered the analysis. This assumption makes it hard to study macro-historical change (Cederman and Daase 2003). In addition, the state-centric assumption obscures actor-type-transforming dynamics inherent in systems change.

While moving the theoretical agenda in the right direction, both Jervis and Wendt fail to provide a satisfactory basis for new systems theory, because they are reluctant to extricate themselves from the debates with Waltzian neorealism and rational-choice theory.

Toward non-equilibrium theory of world politics

Where could one to turn for source analogies with a better bite on macro change? It would be tempting to recommend a return to classical systems theory, but this would be a mistake. Indeed, the track record of this research tradition in IR applications is at best mixed (Mesjasz 1988; Young 1978). As is well known, the initial enthusiasm petered out toward the end of the 1970s due to global modeling's failure to live up to ambitious predictive aspirations and to represent plausible micro-level mechanisms (Rosser 1999, p. 184).

Fortunately, complexity theory provides new foundations on which it may be possible resurrect the systems-theoretic legacy in IR. Derived from modern statistical physics, this kind of theory should not be confused with related, but less suitable, concepts such as catastrophe theory or chaos theory (Rosser 1999). More central to the development of complexity theory were the non-equilibrium approaches developed by European physicists, especially that of the controversial Nobel Laurate Prigogine and his associated, who specialized on the physics of dissipative systems. Aided by computational techniques, the current generation of complexity research has started to make inroads into the social sciences.

The field of complexity theory is broad and growing (Axelrod and Cohen 1999), but here I will focus on recent advances in statistical physics and their applications to social phenomena. Self-organized criticality, a concept coined by the late physicist Per Bak, has attracted much attention. Using a sandpile as a master metaphor, Bak showed that if a steady stream of sand grains drops on it, avalanches will be triggered that follow a power law distribution, not unlike those exhibited by earthquakes (Bak and Chen 1991; Bak 1996; see Buchanan 2000 for a popular introduction). Such distributions have "fat tails," which implies that extreme events are much more likely than would be suggested by less exotic distributions. Examples include forest fires, biological extinction events, traffic jams, and city sizes.

Even more recently, statistical physicists have become interested in the mathematics of dynamic networks (for popular introductions, see Buchanan 2002; Barabási 2002). As opposed to classical random networks, where edges are added randomly, these systems feature a structure that is much more heterogenous. Watts' (1999) so-called small worlds exemplify such deviations, because in a small-world network, occasional long-range links complement dense local connections thus dramatically improving systemic connectivity. Another prominent research program is provided by Barabási and Albert (1999) and others, who argue that the number of connections per node in the Internet is power-law distributed (see also Albert and Barabási 2001). This implies that whereas a very small number of web sites are extremely popular, the number of links drops quickly according to a multiplicative principle as one considers less popular sites.

The difference between modern complexity theory and classical microeconomic approach could not be starker:

Holistic approach. Instead of hoping to understand social systems by decomposing them and analyzing each part in isolation, complexity theorists insist that complex social systems have to be analyzed as wholes. Typically they assume that such systems are composed of large numbers of parts that interact in a non-linear fashion within some space (Cederman 1997, Chap. 3). Rather than leaving the connection between Lake and Powell's "strategic boxes" unanalyzed, complexity theory requires that it be explicitly modeled. Without attention to the context, it would be impossible to connect systemic macro properties to the systems' micro foundations (Schelling 1978).

Non-Equilibrium theory. Whereas the ultimate purpose of microeconomic theory is to derive equilibria, the goal of non-equilibrium physics is to explore transitory processes. Whether these actually produce equilibria is less relevant than studying the mechanisms that constitute the processes. Many processes in statistical physics exhibit strong regularities despite operating far from any global equilibrium. The main task of the non-equilibrium theory is to explore such macro properties and to theorize recurrent transitions between meta-stable configurations, as illustrated by self-organized criticality. This focus liberates such approaches from the metaphysical obsession with unique equilibria, thus opening the door to contingency and historical path-dependence. Significantly, in opposition to chaos theory, complexity theory teaches us that regularities may appear at the macro level despite massive non-linearities and path-dependence in micro-level interactions (Buchanan 2000).

Generative inference. In lieu of nomological causation, generative inference looms large in non-equilibrium theory. Typically, the theorist starts with an observed macro-level pattern. Such macro properties may be based on qualitative observations in time and space, but in some cases the system in question generates a statistical footprint. Such statistical distributions are seen as a reflection of some underlying dynamic process rather than as static manifestations of an invariant covering law (Cederman 2002b). As suggested by scientific realists, the main function of explanation is to discovering the set of mechanisms that produce the macro pattern in question. For example, the power laws discovered by Bak and Barabási serve as the starting point for their attempts to reconstruct the mechanisms that generate the patterns in the first place. This "reverse engineering" approach is thus not in principle dependent on there being a large number of similar cases from which to draw inferences. Unique historical outcomes may constitute the macro pattern the underlying mechanisms of which should be investigated. It goes without saying that world history offers many examples of such singularities and epochal shifts.

Endogenous actors. Liberating the theorist from having to reify social forms, complexity theory offers the necessary tools for endogenization of actors and the configurations they are embedded in (Cederman 2002b). Partly this advantage derives from the fact such theories represent space explicitly, a necessary condition for any attempt to trace the evolution of territorial boundaries. In addition, boundaries may also be expressed through symbolic boundaries in abstract space and through dynamic networks. Agent-based modeling, which is a methodology that is particularly well suited to operationalize complexity theoretic ideas, provides technical solutions to all these modeling problems (Cederman 2002a).

Applications to world politics

In this memo, I have attempted to make the case for a widening of the standard IR repertoire of master analogies to encompass complexity theory and non-equilibrium physics. Interestingly, many of the ideas in the latter fields have been anticipated by sociological process theorists working in the Simmelian tradition, such as Giddens, Elias, and Tilly (Cederman 2002b). Fortunately, recent years have seen interesting attempts to develop systemic theorizing by building on historical sociology (e.g. Hobden and Hobson 2002). However, this is not an argument in favor of abandoning microeconomic analogies, only a call for increased theoretical pluralism and imagination. Rational-choice theory and econometrics are, and will remain, indispensable items in the IR scholar's tool bag, but they are not the only ones and their grip sometimes fails.

Obviously, these meta-theoretical recommendations hinge on the isomorphic fit between real-world phenomena and complexity theory. This is not the place to make that case in detail. Here I can only hint at two types of macro-level distributions that could serve as starting points for non-equilibrium theorizing. Both relate to size distributions, where the object is about wars and states respectively. Since Richardson's pioneering efforts to collect quantitative data about conflict processes in the 1940s, we know that wars are power-law distributed. Figure 1 illustrates that the scale-free relationship is surprisingly strong. Using logarithmic axes, the diagram plots cumulative probabilities $P(S > s)$ as a function of war size s. In Cederman (2003), I draw on self-organized criticality in an attempt to reconstruct the mechanisms that generate this macro-level regularity. It turns out that a slow process of technological change together with contextual decision-making dependencies are sufficient to generate power-law distributed war sizes. If this type of non-equilibrium theorizing is accurate, it implies that war emerges as occasional releases of built-up tensions within the system, very much as anticipated by Gilpin (1981). Thus warfare is not a characteristic of equilibrium states, but rather a phenomenon triggered when the system moves *between* meta-stable equilibria. For further details, I refer to Cederman (2003), which has been attached as an "assigned" reading.

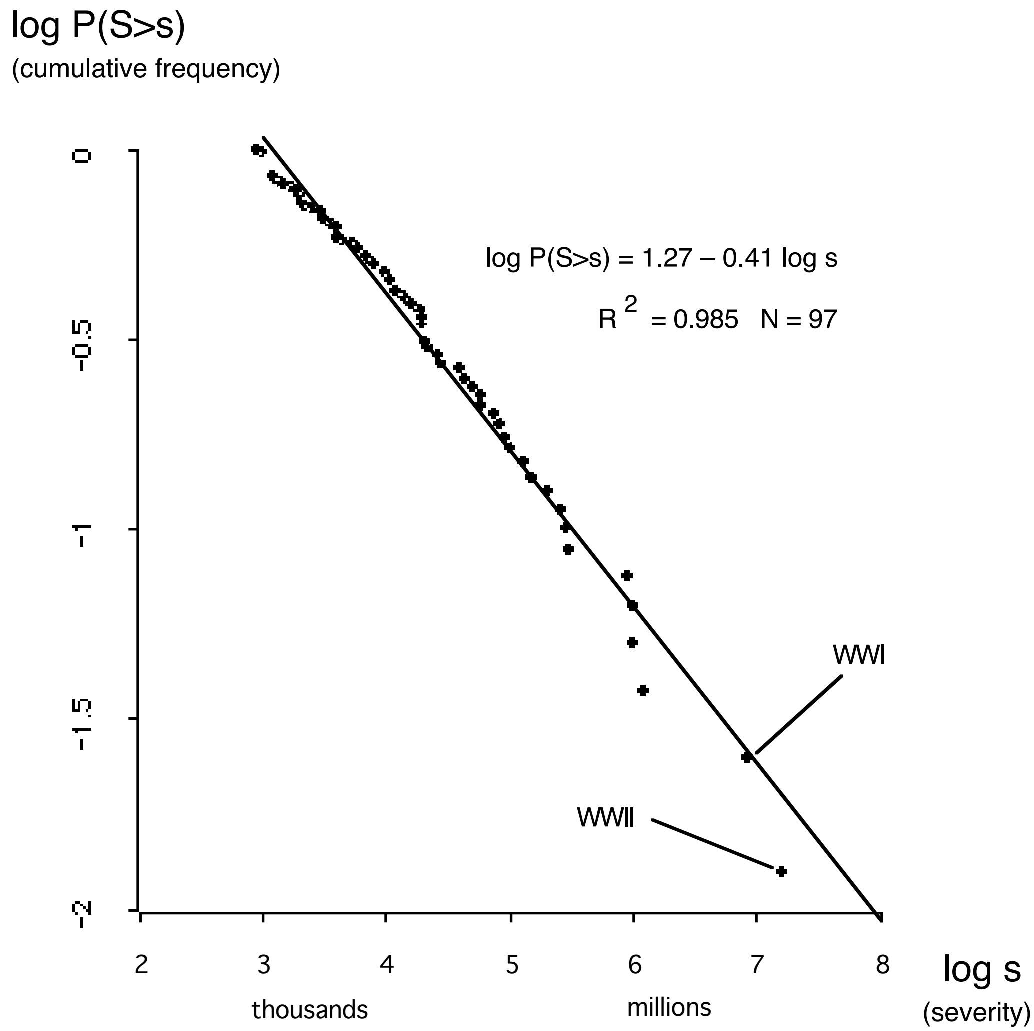

Figure 1. Cumulative frequency distribution of severity of interstate wars, 1820-1997
Source: COW data

Even more recently, I have been exploring distributions of territorial state sizes. Such measures offer a much more informative picture of systemic structure than polarity. Rather than exhibiting scale-free behavior, the data appear to be log-normally distributed (see Figure 2). In this diagram, which also features logarithmic axes, it is clear that the cumulative distribution function is curved rather than a straight line reflecting a power law. The points are well fitted by a log-normal distribution:

$$\log S \sim N(12.3, 1.8)$$

In this case, I have used data on territorial state sizes collected by Lake, Hiscox, and their collaborators. The distribution holds up very well for other years in the dataset, which covers the last two centuries. In addition, my initial findings show that this distribution appears to capture other measures of war size, such as population and troop strength.

While it is too early to tell exactly what mechanisms contribute to such striking regularities, complexity theory offers clues that may prove theoretically valuable. For one, we know from Gibrat's law of "proportionate effect," that multiplicative random walks result in such distributions (Amaral et al. 1998). Economists have long debated whether power laws or lognormal distributions best describe firm size and income distributions (e.g. Simon and Bonini 1958; Mitzenmacher 2002). In any case, a theory of territorial state size would have to point to specific mechanisms that are responsible for generating the macro-level pattern in the first place. It would seem that agent-based modeling will facilitate the search for the micro-level mechanisms in question.

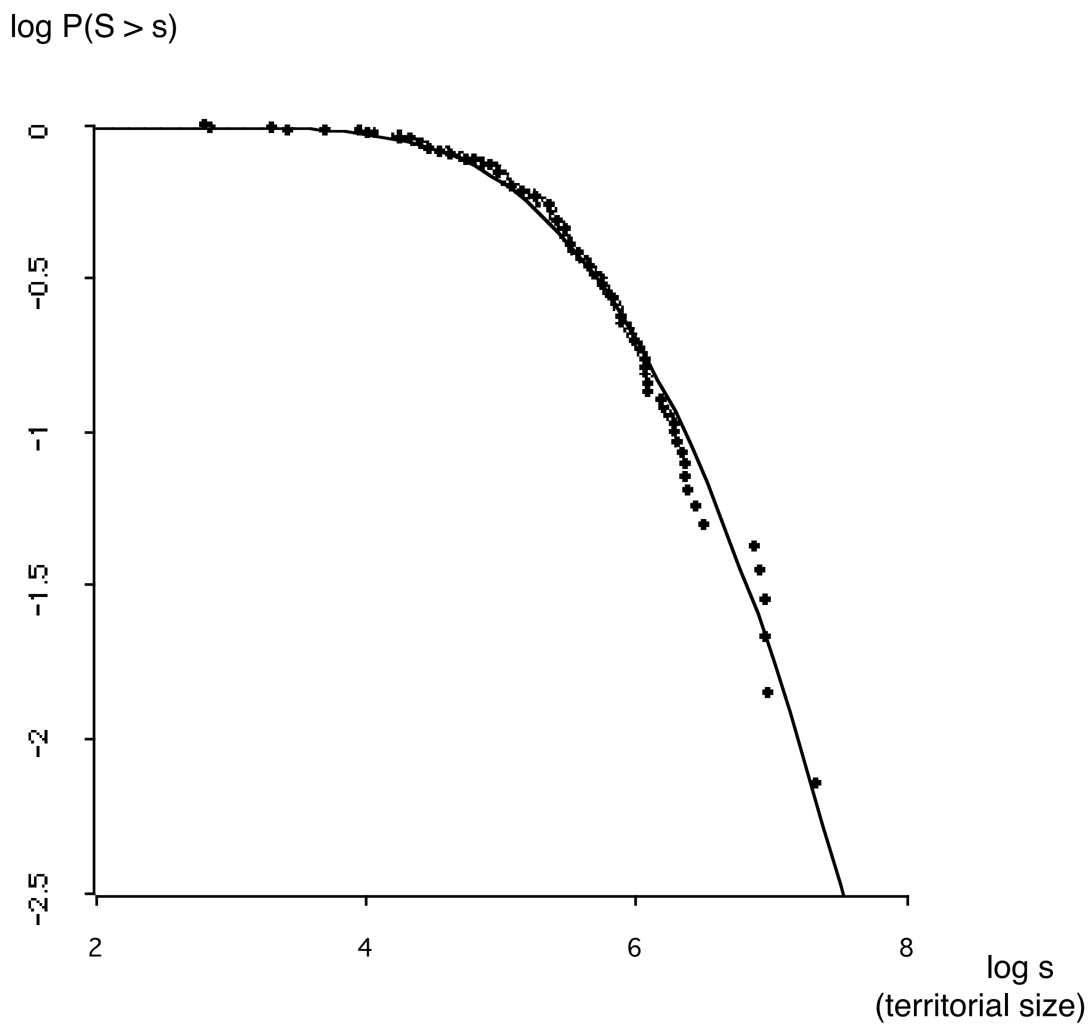

Figure 2. Cumulative frequency distribution of territorial state sizes, 1983
Source: Lake and Hiscox.

In related computational work, I have attempted to reframe the democratic peace as a non-equilibrium process starting with very few democracies leading to high concentrations thereof along the lines of Kant's famous sketch (Cederman 2001a; Cederman and Gleditsch 2002). In addition, I have attempted to assess the effects of nationalist systems change within geopolitical systems (Cederman 2001b).

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