Usage of Recursive in Political Science

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ABSTRACT The article discusses the term "recursive," which has multiple uses in the political science literature. The two principle uses are reviewed, with attention to precedent and technical meanings, and examples are provided of mathematical concepts and their application to political science literature. The problem of divergent meaning is addressed through a survey of potential for reconciliation or possible substitute terminology.

The term "recursive" has at least two uses in the recent political science literature. One is technical; the other is less specific, but also useful in describing certain kinds of phenomena of interest to political science. This divergence means there is some question as to which usage is more appropriate or correct. In this article, I review the origins and uses of the term "recursive," and suggest a way to reconcile the two meanings.

GENERAL USAGE

Of the two meanings of "recursive," the more general is perhaps more familiar. This usage is also the newer of the two, having entered political science through the work of sociologist Anthony Giddens. He describes "human social activities" as recursive: "That is to say, they are not brought into being by social actors but continually recreated by them via the very means whereby they express themselves as actors" (1984, 2). This statement is Giddens' answer to the agent-structure problem in sociology and the basis of his "structuration" theory, which has attracted the attention of political scientists occupied with similar concerns. Notable among these scholars is Alexander Wendt; in his paper, "Agent-Structure Problems in International Relations," he writes:

> It is important to note that one of the intended or unintended effects of state action is to produce or reproduce system structures; consequently, historical analysis is necessary to explain the emergence and persistence of the structural conditions which constitute the medium and conditions of possibility for state action. This recursive quality of structural and historical explanations is the "unity" beneath their "diversity."(1987, 364)

The text suggests that Wendt uses "recursive" in the same sense as Giddens, and the notes and citations to the article reinforce this suggestion. More recently, other political scientists have taken up this usage as well. For example, Clark places quotes around the term "recursive relationship" (1998, 246), and Imbroscio writes of "an interactive and recursive fashion" (1999, 46); both are referring to Giddens' ideas specifically. Elsewhere, Emmelman (1996) describes "recursive decisionmaking" in legal settings. Hopmann, reviewing Jervis's *System Effects*, writes that interaction effects are "not merely additive or linear but are contingent and recursive" (1998, 314).

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In each of the above cases, "recursive" means "mutually influential" or "mutually constitutive." In this usage, to say that A and B are elements in a recursive pair suggests that A affects B while B affects A. As political scientists untangle the nonlinearity of political and social interactions, "recursive" in this sense is a useful term and concept. Many political phenomena comprise mutually influential elements; in studying such phenomena, it is undoubtedly helpful to have a concise way of describing the relationship between these elements.

TECHNICAL USAGE

The problem with the general usage of this term is that "recursive" is used elsewhere in political science with a different meaning to describe certain types of simultaneous equations familiar to quantitative analysis. In recursive simultaneous equations, the dependent variable of one equation is an independent variable in another equation. That is to say, A affects B, but B does not affect A, as shown in the following equations:

$$A = \beta_0 + \beta_{11} x_1 \quad (1)$$

$$B = \beta_0 + \beta_{21} A \quad (2)$$

The term "nonrecursive" is used to describe simultaneous equations in which A and B are mutually influential, as in the following equations:

$$A = \beta_0 + \beta_{11} x_1 + \beta_{12} B \quad (3)$$

$$B = \beta_0 + \beta_{21} x_1 + \beta_{22} A \quad (4)$$

This term is akin to what is implied in Giddens' usage of "recursive." Whether this description is actually what Giddens means is discussed in the following section. Note that the nonrecursive/recursive dichotomy is specific to the domain of simultaneous equations.

This meaning of "recursive" (and "nonrecursive") entered political science via econometrics, originally from mathematics (see Kleene 1935, 223). Its origins in mathematics are not relevant, except as they are antecedent to later usage by midcentury econometricians, who first used "recursive" to describe simultaneous equations. Writing in *Econometrica*, Wold describes models wherein (among other characteristics), "given the development of the exogenous variables and a set of initial values for the endogenous variables, the model allows us to calculate, recursively, the development of the endogenous variables" (1954, 172). Again in *Econometrica*, Strotz and Wold note "that a recursive, or causal chain, system has the formal property that the coefficient matrix

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of the non-lagged endogenous variables is triangular (upon suitable ordering of rows and columns) whereas a nonrecursive, or interdependent, system is one for which this is not the case" (1960, 417). This distinction will be clear to students of simultaneous equations—but almost no one else. What this means, however, is exactly the distinction illustrated in the previous recursive equations; recursive (in the technical sense) models are not mutually influential, showing instead unidirectional causality. Previously, Bentzel and Hansen (1954–1955) used the terms "recursive" and "interdependent" to draw the same distinction.

Recursive (and nonrecursive) modeling techniques soon passed to political scientists, especially those scholars concerned with quantitative methodology. Alker describes these techniques in volume two of his *Mathematical Applications to Political Science*, drawing a distinction between "hierarchical versus circular causation." He calls models of the former "recursive systems," but the latter are variously called "reciprocal" or "circular" systems (1966, 15).

Studies applying recursive models began to appear in political science journals soon thereafter; for example, in 1969, Nie, Bingham Powell, and Prewitt employed recursive models in their study of participation. By 1977, recursive models were familiar enough that Sigelman could parody their use, describing this advanced technique for methodological success: "the Recursive Route Restrictor, which simplifies the analysis of complex causal systems by permitting only undirectional arrowdynamic [*sic*] causation" (1977, 304).

However, not all contemporaneous uses of "recursive" demonstrate quantitative sophistication. In their discussion of global diplomacy, Russett and Lamb write:

> Thus whereas some feedback or other recursive mechanism may plausibly be hypothesized for the interaction of diplomatic exchange with any of the other influences (e.g., heavy commercial interactions promote a need for consular and ambassadorial personnel in the other country, and their presence then in turn facilitates even more trade). (1969, 49)

The parenthetical example illustrates precisely what Russet and Lamb mean by "recursive"—the mutual influence of two elements in a system, very much akin to Giddens' later usage. This is the only appearance of the term in the article, and Russet and Lamb do not use recursive (simultaneous equations) models in their analysis.

As econometricians in the 1950s began to adopt "recursive" to describe simultaneous equations, linguists also began employing the word. In the April–June 1954 issue of *Language*, Bar Hillel invoked "special cases of RECURSIVE DEFINITIONS [*sic*]." From there, the term was adopted by Chomsky, citing Bar-Hillel: "Bar-Hillel suggests that recursive definitions may be useful in linguistic theory; whether this turns out to be the case or not, I agree in this instance with the spirit of his remarks" (1955, 45). Chomsky's later work suggests that recursive definitions did prove useful, and a recent paper by Hauser, Chomsky, and Fitch defines recursion as the capacity to take "a finite set of elements and yield . . . a potentially infinite array of discrete expressions" (2002, 1571). It is possible, but far from certain, that Giddens adopted the term from Chomsky's work.

SIMULTANEITY

As noted, the technical meaning of recursive depends on the simultaneity of the processes described. It is this kernel that differentiates it from the general meaning—but only within the narrow domain of simultaneous equations. That is, if the process in question is not explicitly simultaneous, then the general usage is acceptable and perhaps preferable. The following equations provide a sketch of this distinction. Where the subscript t indicates time, mutual influence between two elements simultaneously can be illustrated as:

$$A_t \leftrightarrow B_t \tag{5}$$

Mutual influence between two elements over time can be expressed as:

$$A_t \rightarrow B_{t+1} \rightarrow A_{t+2} \rightarrow B_{t+3} \rightarrow \cdots \rightarrow A_{t+n-1} \rightarrow B_{t+n} \tag{6}$$

The arrows in these diagrams can indicate influence, constitution, or causality—however one wishes to characterize the interaction of two elements. In equation 5, the two elements are mutually influential. This is recursive in the casual sense, but clearly "nonrecursive" in the technical sense. In equation 6, the same interaction of the elements expands to account for the passage of time; so long as the interaction does not occur simultaneously, equation 6 depicts a recursive relationship in the technical sense.

The trick for political scientists is that the causal chain depicted in equation 6 may unfold at time scales that are difficult to measure by readily available means. In these cases, simultaneous equations provide a shortcut to describing the period-to-period variation in the phenomena of interest. Such phenomena might be strictly recursive while having the appearance of being instantaneously mutually influential—that is, "nonrecursive" in the methodological sense—because they unfold along time scales below the threshold of our ability to measure events. The simultaneity (or not) of the interaction makes all the difference.

This temporal aspect seems to be the source of confusion regarding usage of "recursive." For example, Russett and Lamb suggest that their trade-consular dynamic is both recursive and a feedback mechanism, which is correct if they mean that the mechanism plays out over time (as in equation 6); however, their description of that dynamic makes it easier for a reader to infer simultaneity (equation 5) as their intended model. Likewise, if

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Giddens means that actors and activities are "continually recreated" over time—which does seem implicit—then his usage is correct, although perhaps not as specific as it could be.

Even if Giddens' usage is correct, it still unlikely that he has in mind the sorts of models that quantitative methodologists consider recursive. Thus, there might be two correct, slightly different uses for "recursive." The problem then is not only that the word means something very specific for one subdiscipline and something else for another; if each subdiscipline recognizes the other's usage, they will still be able to communicate effectively. The situation would then be akin to the British and American usage of "billions"—merely an idiosyncrasy of the respective parties and something to watch out for. Instead, the real problem for political science is that neither party understands the nuance of the other's usage. Methodologists tend to assume that any nontechnical use of "recursive" is incorrect, while relatively few nonmethodologists realize that there is a technical use in the first place. This misunderstanding makes it difficult for each party to communicate their ideas across the methodological divide.

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CONCLUSIONS

Both uses of "recursive" are helpful to political science, but it is likely in the best interest of the discipline to settle on one meaning. The irony here is that "recursive" in its methodological sense is too valuable to lose to dilution, while its complement, "nonrecursive," is too technical to be useful in ordinary contexts. Political scientists then have no succinct way to describe systems that are simultaneously mutually influential. One option is to continue using "recursive" in both its technical and nontechnical senses, but to briefly qualify the term so as to draw the necessary distinction. Three additional alternatives have arisen in the course of this review—"reciprocal," "circular," and "interdependent." "Reciprocal" is most familiar, but it also has a technical meaning that could lead to confusion. "Circular" and "interdependent" are safer alternatives, although some elaboration might be required. Other candidates include "coadjuting," "symbiotic," "mutualist," "synallagmatic," and "interactive," which all have similar, but slightly different meanings.

The reader will likely make up his or her own mind, but I favor maintaining the technical usage of recursive and nonrecursive. This should not be taken as criticism of Giddens, Wendt, and others, all of whom have made significant contributions to the study of society and politics. The discipline might, however, decide that the term "coducive" more accurately describes the sorts of phenomena now called "recursive" in nontechnical usage. This word also means "mutually influential," and arises from the same root as "inductive," "reductive," and "conducive." As terms of art go, "coducive" is neither opaque in meaning nor heavy on the tongue. If "recursive" will not do, "coducive" is an apt substitute.

Whether or not any substitution is made, readers who range widely in the political science literature should be aware of the divergent usage of "recursive." This awareness is especially necessary for students not yet wedded to one particular subdiscipline within the field. Authors should be aware that while "recursive" is a useful term across the discipline, its overly casual use can sometimes decrease—rather than increase—the reader's understanding. ■

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