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INTRODUCTION

To most of us who spend our professional lives in scientific inquiry, questions of epistemology and methodology tend to be as remote and distasteful as the most recent discoveries in biochemical research laboratories are to ordinary farmers. Many scientists make significant contributions to knowledge unhindered by, even aided by, their disinterest in formal problems of methodology. Yet, unlike farmers who can confidently depend on others to be concerned with the biochemistry of porcine metabolism, scientists must, when it becomes necessary, face the methodological and epistemological questions themselves.

Social science, because it developed much later than did natural science, benefited greatly from the adaptation of the systematic methodology developed for the latter. But, with progress in social science, it has become increasingly clear that some changes of emphasis in methodology are necessary.

Among the methodological problems that are much more acute in the social than in the physical sciences are those having their origin in the difficulty in performing controlled experiments on social phenomena. In the absence of such experiments, social scientists must use the data generated by a single, complex, uncontrolled experiment that is the history of society in its entirety. Under such a circumstance, a number of familiar notions become rather ambiguous and must be redefined carefully if we are to use them in formulating and analyzing problems in social sciences.

One of the concepts that seems quite indispensable in our thinking is "causality." It is quite true that we could conceive of a system described by a set of simultaneous equations, in which all variables are determined simultaneously. However, even in such a system, we often talk of "solving the system in terms of parameters," implying in some sense that parameters are the "cause" of a specific solution for the variables of the system. When an analyzed system is used as a datum for normative analysis, it becomes crucial to pick out those variables and parameters that are either (1) under the direct control of the decision maker, or (2) "given" in the sense that they are not influenced by other variables within the system under consideration, and distinguish them from those variables that are (3) influenced by other variables in the system.

The possibility of identifying "causal" relations is intimately related to the possibility of classifying variables into a hierarchy of sets, levels I, II, III, and so on. Variables belonging to higher-numbered sets are influenced by those in the lower-numbered sets, but the former do not influence the latter. (Variables within any set may, but need not, influence each other.) When such a stratification exists, then we may say that the variables in the lower-numbered sets are the "causes" of the variables in the higher-numbered sets. This type of hierarchical structure also provides the justification for ignoring the variables in higher-number groups when the object of an investigation is restricted to the behavior of variables in lower-numbered sets. Laboratory experimentation is a technique for artificially creating a particularly simple form of hierarchy among variables. The second chapter in this volume undertakes to define rigorously the structural relations and meaning of "causality" in this context.

As mentioned earlier, in dealing with social phenomena, it is frequently impossible to define such a hierarchical structure, partly because social systems are often more complex than physical systems, and because the laboratory experiments which artificially create a hierarchical structure are not available to the social scientist.

However, nature is not completely unkind to social science. While exact hierarchical structures are not likely to be encountered, many of the situations that social scientists are interested in can be represented by "approximately" hierarchical systems. But the question immediately arises: do only approximately hierarchical systems exhibit characteristics similar to those possessed by exactly hierarchical systems? More fundamentally, what do we mean by "approximately" hierarchical?

Alternatively, nature may sometimes present us with a situation that can be represented by two or more subsystems which are "approximately" unrelated to each other. Here again the same questions arise. In what sense, if any, are the results valid when one of such a set of "approximately" unrelated subsystems is analyzed as though it existed in complete isolation? What do we mean by "approximately" unrelated?

We deal with these questions in the fourth and fifth chapters in this book. It turns out that the answer depends crucially on the time period over which the system is observed and on the closeness of approximation to the hierarchical structure (to a collection of unrelated subsystems). More specifically, suppose that we treat an "approximately" hierarchical system as though it were exactly hierarchical (a set of "approximately" unrelated subsystems as though such subsystems were completely unrelated) and require that the resulting predictions we make about the behavior of the system be within a predetermined accuracy.

Then, for any required degree of accuracy (not exact), we can specify: (1) a time period and (2) the largest deviation permitted from the exact hierarchical structure (or the set of completely unrelated subsystems) such that within this time interval the specified accuracy of the prediction will be maintained. One can trade between the length of the time interval and the degree of approximation; i. e., for a given degree of accuracy of prediction, the closer the system is to the exact structure required, the longer the time interval over which the accuracy of prediction will be maintained.

A second but equally important result obtained in the fourth and fifth chapters in this book is concerned with the behavior of the approximate system after the above time interval is over. It is shown that for any approximate system there exists a time interval (which, of course, depends on the degree of approximation and the accuracy demanded) such that, after it has passed, scalar indices representing sets of variables at different levels of hierarchy (in different, nearly unrelated, subsystems) can be defined, and the behavior of the system defined entirely in terms of these indices, or aggregates.

Finally, and this is perhaps the most important result, it is shown that even after all the "approximately" zero causal relations in the system have worked themselves out, the internal structure of each set of variables at a particular causal level (or of each of the "approximately" unrelated subsystems) will be almost the same as would have been the case had the approximations been exact, even though the levels and rates of change of such sets of variables as a whole will generally be quite different. In other words, short-run equilibrium configurations within such sets of variables are approximately maintained as part of the long-run behavior of the system as a whole. This is what makes possible the aggregation into indices just mentioned.

These results are rigorously stated and proved for linear systems in the fourth and fifth chapters in this book. The sixth chapter presents the theorems in rather less technical form and applies them to the analysis of two illustrative examples drawn from the field of political science. The seventh and eighth chapters extend the results to the von Neumann model of production, both in terms of prices and in terms of outputs; the restriction to linearity is removed in that context, so that the results are known to hold for certain classes of nonlinear systems as well. In addition, since little is known about the behavior of such models in the exact hierarchical case, much of the seventh and eighth chapters consists in examining such behavior.

One of the major consequences of the unavailability of controlled experiments in social sciences is the lack of a powerful technique that often permits physical scientists to measure parameters of their systems. During the past twenty years, economists have developed statistical methods designed to deal with the problems created by the fact that their data are generated not by simple experimental settings but by complex simultaneous equation systems. Although the point was not emphasized initially, it can be shown that the method developed cannot cope with the data generated by a completely simultaneous system. In fact, the method presupposes that the system generating the data is an exactly hierarchical one. As stated previously, the systems generating economic data are not likely to be exactly hierarchical but only approximately so. Under the circumstances, how good are the simultaneous equation methods?

The third chapter in this book attempts to answer this question. It is shown that the properties associated with the simultaneous equation estimators hold approximately for approximately hierarchical systems. (The exact meaning of this statement is rather technical and is given the third chapter.

The essays collected here are concerned primarily with the logical foundations for choosing a methodology, and not with more practical problems of actually defining criteria that can be used to choose one methodology over another. While the latter are undoubtedly important, we have limited ourselves to the more abstract question discussed in this introduction, as it is in itself a difficult enough and important enough problem — one that must be dealt with if social sciences are to make systematic contributions to our knowledge of man and society and to our techniques for guiding social and economic progress.*

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* A word about terminology is certainly in order here. In this introduction, we have spoken of "hierarchical" structures and "sets of unrelated subsystems." These correspond to what are called in most of the essays "decomposable" and "completely decomposable" systems, respectively. Unfortunately, however, as these papers were not written originally for this book, Chapter 4 uses "decomposable" in place of "completely decomposable." This corresponds to one of two fairly common usages (in which our "decomposable" is called "reducible") but is not consistent with the terminology of the other essays. The context will always prevent confusion.

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Causal Ordering and Identifiability[1]

HERBERT A. SIMON

1. INTRODUCTION

In careful discussions of scientific methodology, particularly those carried on within a positivist or operationalist framework, it is now customary to avoid any use of the notion of causation and to speak instead of "functional relations" and "interdependence" among variables. This avoidance is derived, no doubt, from the role that the concept of causality has played in the history of philosophy since Aristotle, and particularly from the objectionable ontological and epistemological overtones that have attached themselves to the causal concept over the course of that history.

Empiricism has accepted Hume's critique that necessary connections among events cannot be perceived (and hence can have no empirical basis). Observation reveals only recurring associations. The proposition that it is possible to discover associations among events that are, in fact, invariable ceases to be a provable statement about the natural world and becomes instead a working rule to guide the activity of the scientist. He says, "I will seek for relationships among events that seem always to hold in fact, and when it occurs that they do not hold, I will search for additional conditions and a broader model that will (until new exceptions are discovered) restore my power of prediction." The

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[1] I am indebted to Tjalling C. Koopmans for his valuable suggestions and comments on earlier drafts of this chapter, particularly with regard to the discussion of the relation between causal ordering and identifiability. A distinction between endogenous and exogenous variables similar to the concept of causal ordering here developed was made by Orcutt [1952]. For a discussion of the incorporation of the notion of causality in a system of formal logic, see Simon [1952].