*From POET to PISTOL: Reflections on the Ecological Complex**

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Some macroecologists study population characteristics using a single variable, while others specify a system of interrelated variables. The purpose of this paper is to offer an ecological model which is theoretically appropriate and correctly bounded. Based on population (P), information (I), space (S), technology (T), organization (O), and level of living (L), or PISTOL, it is argued that the addition of two variables to the most famous ecological model (POET), namely L and I correctly bounds the POET model since each component is theoretically important.

Introduction

For analytical reasons, manageability, or the availability of data, theorists often concentrate their efforts on one or a few global properties. Examples include Durkheim (1949) [1893], who concentrated upon the division of labor, Malthus (1798), whose focus was on population, and Marx (1967) [1867], who used technology to evaluate the means of production. The value of such single-component analyses is beyond debate. It is also clear that none of these components operates in a vacuum. Thus, a model which relates these variables to one another would be of value for understanding the relationships among variables and for comparing societies or for comparing a single society at different points in time.

The value of such a model becomes evident if the model is neither overbounded nor underbounded relative to the empirical system and it is isomorphic with the system, that is, if congruency exists between each component of the model and each corresponding component of the social phenomena being modeled. For example if only population (P) and organization (O) were empirically related, then an analytical model specifying relationships between population, organization, and technology (POT) would be overbounded. On the other hand, if population, organization, and technology were empirically related, a model specifying the relationships between only two variables (PO, PT, or TO) would be underbounded, with only POT isomorphic to reality.

It can be suggested that an underbounded model is inadequate if the

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essential variables and the interrelationships between these variables are neglected. However, an overbounded model is also logically inadequate, and use of such a model may lead to erroneous parameter estimates. The adequacy of a model depends on whether a unique set of macrosociological variables is related empirically.

The best known multivariate macroecological system is in the ecological complex developed by Duncan and Schnore (1959), consisting of population, organization, environment, and technology (POET). Similar to Ogburn's (1951) formulation, the POET complex emphasizes environment, an element which Ogburn mentioned only in passing. The efficacy of the ecological complex is not a matter of debate since the POET model has been evaluated in a number of discussions and applications (see Duncan 1959; 1961; 1964; Duncan and Schnore 1959; Schnore 1960–1961; 1962; 1964).

A more recent theoretical exposition of POET was offered by Micklin (1984) who suggested that each of the four components can be treated as independent or dependent variables, though most studies focus upon organization as the dependent variable. Poston, Frisbie, and Micklin (1984, p. 96) also lament the apparent tendency of analysts to concentrate on POET as a "heuristically useful typology," while the ecosystem framework is generally neglected.

Other analysts have commented on the four components. Analysts of the environment include Hawley (1968; 1981; 1986), Michelson (1970), and Berry and Kasarda (1977); population has been discussed by Berry and Kasarda (1977), Poston and White (1978) and Hawley (1986); organization has been analyzed by Berry and Kasarda (1977), Frisbie and Poston (1978), Aldrich (1979), Hawley (1986), Carroll (1987; 1988), Hannan and Freeman (1977; 1988) and Delacroix, Swaminathan, and Solt (1989); technology has been treated by Frisbie and Clarke (1979; 1980). But for the most part analysts of POET relate a single variable from one component to the other three components in a recursive model, such as Sly (1972) did by relating migration (P) to organization (O), environment (E), and technology (T).

It appears the POET model is probably not overbounded, but the model may be underbounded, suggesting, in turn, the existence of alternative five and six variable models. While empirical testing of these alternative models may not be possible, one feasible strategy is to examine a concrete society by generating those variables germane to the multivariate macroecological model. The purpose of this paper then is to utilize this strategy to generate all possible variables.

The Model

Analysis of various combinations of variables forming an ecological system is useful to generate a number of alternative systems. What is required is a method to demonstrate which of the variables are interrelated. This can be accomplished using a basic societal model and, then, ascertaining which of the variables are necessary to ensure the ecological adaptation of that society.

A minimal ecological model includes a population (P) which is located within a given spatial area (S) at a given point in time. This population has adapted positively, negatively, or neutrally to the spatial area, resulting in level of living (L). Inasmuch as level of living can be interpreted as a measure of ecological adaptation, L represents a crucial variable.

Level of living (L) can be operationalized a number of ways. Average number of calories consumed per capita, for example, may be an appropriate means to operationalize level of living for nonindustrialized societies (see Bailey 1982), while average income may be a more appropriate measure for industrialized societies (Bailey 1982).

To this point, the ecological model is composed of three components, P, S, L, each of which is interrelated in a systemic manner. As a case in point, when L is low and the amount of food is insufficient, then starvation will occur, thereby decreasing P. A low L could also result in failure of the society to maintain its boundaries. Conversely, if P is high, then L will be effected, or if S is sufficiently small that natural resources are unavailable, then L will also be affected. The issue then becomes one of whether this three-variable model is isomorphic with empirical reality; that is, the model is neither overbounded nor underbounded. The task is to think of factors other than P or S that could affect the degree of ecological adaptation of the society when level of living is measured.

Another variable affecting level of living is technology. At a given point in time and within a specified spatial environment, level of living produced is affected by the tools which generate finished products from the resources available within these spatial boundaries. Thus, two societies equal in population size and available environmental resources may experience quite different levels of living if one society employs tractor technology in agriculture, while the second society is limited to the use of hoes.

Now consisting of P, S, L, and T, the proposed model remains underbounded if other variables are found to affect any of the system variables. The addition of organization (O) to the model, the manner in which the population is organized, has a profound effect upon the efficiency with which technology is utilized to adapt ecologically within the spatial boundaries at a given point in time. Organization also affects the level of living.

The model now consists of P, S, T, L, and O, but a question remains as to whether other variables may affect the system as well. Type of information (I) can affect level of living. Given the elements of the model it may be feasible to produce either food A or food B despite the fact one food form is more nutritional. If the available knowledge determines the production levels of the less efficacious commodity, then the level of living if affected. Conversely, the benefits derived from the product result in an increased level of living. Information (I) also includes values as well as knowledge, thereby affecting decision making and social action, and hence each component in the system, including the level of living. If a society does not condone the eating of beef, as in the case of India and sacred cows, one major food source is lost thus clearly having an effect on level of living.

Information refers to culture which includes religion, ideology, and science. Examples include technical information on construction or repair. Religious ideologies and cultural values are equally salient examples. It is also noteworthy that information often is discussed as a component of technology. Lenski (1970, p. 37) defines technology as "information, techniques and tools," but it may be preferable to separate knowledge and information from tools, since the components represent broad categories.

The PISTOL model shown in Figure 1 may now be correctly bounded inasmuch as the ecological requirements are met; each variable is necessary to the system and together these are sufficient. The model includes a population acting over time to adapt to its environment, resulting in a given level of living (L), which is effected in turn by population size (P), space (S), technology (T), organization (O), and information (I).

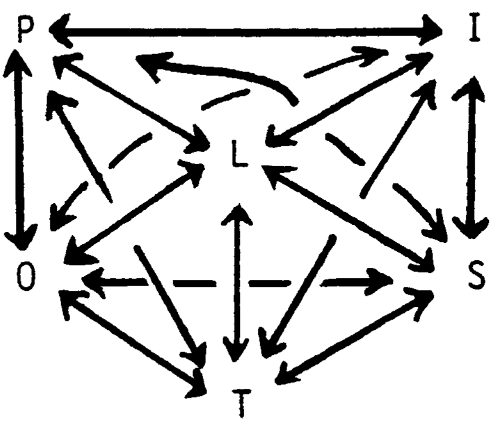

Figure 1

The PISTOL model. KEY: P is population, I is information, S is space, T is technology, O is organization, and L is level of living. Double-headed arrows indicate reciprocal relationships among all pairs of variables.

The PISTOL model is set at a given point in time in a given spatial territory which includes natural resources, climate, and air space. Available materials provide sustenance in the form of energy, and these can be utilized, either in a natural or transformed state, as tools (technology). Such tools serve as a means for growing food and the production of shelter from available raw materials.

A population's success in maximizing its adaptation (level of living) depends upon the size of the population that must be provided for as well as the raw materials necessary for producing food, shelter, and other necessities. In addition, success is dependent upon the way the population is organized to utilize space and nature resources and to operate tools. Nonefficient organization yields a level of living lower than the maximum that the population/resource ratio might allow.

Finally, the efficient operation of all five variables singly and in the aggregate is dependent upon the cognitive ability of the society in that knowledge, beliefs and values are applied to the adaptive process. Decisions are made about the desired level of living, the societal boundaries, and how resources and technology are to be utilized.

Nature of the Model

One advantage of the PISTOL model is that it is based upon an examination of a concrete, spatially and temporally located society, and demonstrates how society works at the macro level. Each component affects level of living and at least one other component of the model. No other components qualify on this basis, therefore the model is correctly bounded.

Although the six system components are referred to in this report as variables, each represents a component or collection of variables. Population (P), for example, can be measured as population composition, size, or density (see Delacroix, Swaminathan, and Solt 1989; Bailey forthcoming).

Although the PISTOL model focuses upon internal relations, exchange is also included as the model analyzes the size or amount of change of each component regardless of how that change originates. The relationship of one society to another does not change the model but provides additional complexities in empirical analysis. Thus, a given society could achieve a higher level of living through expanding territorial boundaries, changing technology, or through trade or foreign aid. Similarly, an increase in population size (P) may result from natural increase as well as through immigration.

Operationalization of each model component is difficult, as many possibilities exist for each. Examples include Bailey (1982) who operationalized level of living in terms of number of calories available to the population, life span of the population, and income. Many other possibilities also exist as the literature on social indicators has demonstrated (Land and Spilerman 1975). The PISTOL model components represent macro level characteristics of society while other variables which could be specified represent micro level characteristics of individuals (Bailey 1990).

These six components can be quantified in two ways. First, aggregate values for each can be determined. Examples of continuous populations include the measurement of population in terms of size, level of living as total number of calories available, the measurement of organization by the jobs available, and technology by the number of tools.

Second, five components can be measured as distributions, thus providing ordinal or nominal variables. These distributions include population among different strata of the level of living which yields class structure, distribution of population into occupational categories to yield division of labor, and a residual distribution of population over space.

Concluding Remarks

The PISTOL model includes variables that are essential in order to avoid underbounding. Level of living serves as the primary indicator of whether a social system is operating efficaciously. L represents an indicator of ecological adaptation and of state of the system. An adaptive social level is important both to ecology and to functionalism. Formulating level of living as a continuous variable is important, because it yields a model suitable for comparing different societies, including highly complex societies.

Level of living is important to sociological analysis as noted by Land and Spilerman (1975) and Krebs and Schuessler (1989). Level of living affects variables, as well as being affected. Ceteris paribus, society's level of living is crucial to determining the population size that can be supported, the spatial area it can maintain, and the extent of division of labor.

The informational component also has value beyond assuring that the model is not underbounded. One such advantage is a link to systems models which emphasize the processing of energy and information (Miller 1978). Ecological models which emphasize energy (Cottrell 1955) provide a point of contact with modern systems theory, but often such models neglect information processing. Duncan (1964) advanced the congruence of ecological systems theory and modern general systems theory through his emphasis on information and energy flow in ecosystems, stating (1963, p. 43):

> The objective (is) to indicate that a fundamental feature of any ecosystem and its component subsystems is the flow of requisite materials, energy and information.

Another advantage of including information is that this component facilitates the study of decision making. Knowledge is useful for making decisions about population size including fertility and migration policies, boundary expansion or constriction, resource utilization, and the adoption of new technology. The salient point is that decision making lessens or eliminates problems of teleology and tautology.

Inclusion of the informational component also addresses past criticism that ecologists have neglected or misused cultural and social factors (Alihan 1938). The ecology of Burgess (1925) and Park (1936) was severely criticized in this regard. Neoclassical ecology (Duncan and Schnore 1959; Theodorson 1961; 1982) reacted to this criticism by including social organization. However, this did not thwart further criticism that ecology is prone to tautology and teleology, while exhibiting mechanistic, economic, or biological determinism (Willhelm 1964; Bailey and Mulcahy 1972).

Inclusion of the informational component may avoid some of these problems, since this component provides a convenient mechanism for including values, beliefs, and knowledge as ideational factors that affect ecological decision making. One result is the reduction of bifurcation of ecological and nonecological approaches to sociological understanding.

ENDNOTE

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