POLICY AND THE STUDY OF THE FUTURE:
GIVEN COMPLEXITY, TRENDS OR PROCESSES?

Ronald D. Brunner

Garry D. Brewer

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Ronald D. Brunner
The University of Michigan

and

Garry D. Brewer
The Rand Corporation**

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ABSTRACT

At this early stage in the scientific study of the future for policy purposes, a number of important methodological choices face social scientists. One important choice concerns the relative utility of forecasting by extrapolating trends or by using process models. The former is the more familiar method, and the latter is considered to be the more promising.

After introducing a minimum number of essential concepts in the formal study of political systems by way of presenting an illustrative process model, we explore the effect that complexity has on the analytical tractability of the system. Consequent implications for the scientific study of policy are sketched out as appropriate.

POLICY AND THE STUDY OF THE FUTURE: GIVEN COMPLEXITY, TRENDS OR PROCESSES?*

"...Although there are so many tiny parts that your eyes can see,
You'd never ever guess what it's going to turn out to be...."

A random thought from
Sesame Street

Introduction

At this early stage in the scientific study of the future for policy purposes, a number of important methodological choices face social scientists. One important choice concerns the relative utility of forecasting by extrapolating trends or by using process models. The former is the most familiar method,[1] and the latter is considered to be one of the most promising.[2]

This choice and the issues rooted in it were raised at a symposium on "The Nature and Limitations of Forecasting" sponsored by the Commission on the Year 2000 of the American Academy of Arts and Sciences.[3] Wassily

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*Some material in this paper is taken from our book Organized Complexity: Empirical Theories of Political Development (New York: Free Press, 1971).

[1] Daniel Bell, "Twelve Modes of Prediction -- A Preliminary Sorting of Approaches in the Social Sciences," Daedalus, Vol. 93 (Summer 1964), p. 850.

[2] Ibid., pp. 872-3.

[3] Daedalus, Vol. 96 (Summer 1967), pp. 936-47.

Leontieff pointed out the conflicting assumptions of the two methods and advocated the use of models for policy purposes.

> There are predictions by models and predictions by trends. Predictions by models are based on the belief that it is possible to view the world as one whole with separate parts that are in some way interrelated. Prediction by trends gives us a view of the world as if it were a handful of sand, each particle distinct from the others.... To discuss policies not in a deterministic way, but as a problem of choice, I think you must work with models. To build policies into trends is difficult.[4]

Using the example of stock market forecasting, Martin Shubik took the position that the "chartists" who extrapolate trends cannot be dismissed so easily because of time constraints on the decision process.

> There are the chartists and the fundamentalists. The fundamentalists want to discover as much as they can about the firm--where its technology is going and so forth--while the chartists draw some linear extrapolations of what is going on and invent such phrases as "when the thing has heads and shoulders." You cannot idly dismiss the chartists, because in one sense a key to forecasting is the amount of time one has available in the decision process to make a statement about the future. A chartist can come up with some sort of fairy tale in ten or fifteen minutes. If you do not have more time, perhaps that is the best you can get.[5]

Shubik goes on to advocate the construction of

> an incremental systematic process that involves, among other things, linking large data-processing procedures with models or conceptual frameworks. This would give an opportunity to link the fundamentalist and chartist approaches.[6]

We reconsider this and similar proposals in the Conclusion of this paper.

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[4] Ibid., p. 941.

[5] Ibid., p. 945.

[6] Ibid.

Two lines of inquiry can be used to clarify empirical distinctions between the two methods, particularly the underlying assumption about the consequences of failing to "view the world as one whole with separate parts that are in some way interrelated." One is a small computer simulation model of modernization and mass politics developed to trace patterns of demographic, economic, and political change in two of the less developed countries.[7] Though merely a first approximation, this model is sufficiently broad in scope to serve the present purposes. The other is the Ando-Fisher theorem on the decomposability of systems, which defines some of the circumstances under which system components can be separated and studied independently.[8] We wish to explore the nature of the interdependence in social systems, to show how systems might be decomposed into their component parts for analytic purposes, and to relate the results to the choice of models in policy analysis and projection.

After introducing some essential concepts in the formal study of political systems, we provide an overview of the model and assess the degree of interdependence among its components. Then we introduce the Ando-Fisher theorem and use it to assess the error involved in abstracting political trends from the rest of the model. The fourth section summarizes the limitations of the fundamentalist approach, and the Conclusion considers some general proposals that compensate for these limitations.

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[7] See the essay "Modernization and Mass Politics" in Brunner and Brewer, op. cit.

[8] See Albert Ando, Franklin M. Fisher, and Herbert A. Simon, Essays on the Structure of Social Science Models (Cambridge: M.I.T. Press, 1963), pp. 92-106, 108-9.

Formal Systems

The difference between the chartist and fundamentalist approaches can be stated concisely if we conceive of a system as a state vector X_t and a set of relationships G.

$$X_t \equiv \begin{vmatrix} x_{1,t} \\ x_{2,t} \\ \vdots \\ x_{n,t} \end{vmatrix} \qquad (1)$$

$$X_t = G(x_t, x_{t-1}, \ldots)$$

The state vector is merely the set of variables and parameters needed to describe the state of the system at any point in time. The relationships G are hypotheses about process, inferred from the observation of real world systems, describing how the components change as a function of each other through time. (X_t is included on the right side of the equation because one component $x_{i,t}$ may be a function of some other component $x_{j,t}$ within the same time period, as in the example considered below.)

The structure of a class of systems (e.g., countries in a region) is the set of variables X_t and the set of relationships G. Together they constitute a theory, a temporary commitment to and representation of the phenomena of importance in the systems. A model of any one of the systems is the general structure with the magnitudes of the variables and parameters specified to represent the particular context. The behavior of a model is the set of time series of the $x_{i,t}$ (the individual components of X_t) which are produced as the model generates successive state descriptions.

The chartist approach to studying the future of systems assumes at least implicitly that the connections among different components either do not exist according to a theory, or that they are sufficiently weak in any particular system that they can be safely ignored. The value of any component $x_{i,t}$ at any time t depends only on its previous values and random disturbances u (which may or may not be included in the analysis). Thus

$$x_{i,t} = f(x_{i,t-1}, x_{i,t-2},\ldots) + u \tag{2}$$

For example, a very simple means of extrapolating rural population growth is the relationship

$$x_{1,t} = (1 + a)x_{1,t-1} + u \tag{3}$$

in which $x_{1,t}$ is the size of the rural population at time t and a is the rate of natural increase. $x_{1,t}$ is independent of the other variables in the system.

The fundamentalist approach assumes that at least some of the possible interdependencies exist in general and are sufficiently important in the specific country. The behavior of each component may depend upon its past behavior and random disturbances u as well as on other variables in the system. Thus

$$x_{i,t} = f(x_{i,t-1},x_{i,t-2},\ldots,x_{j,t},x_{j,t-1},\ldots) \tag{4}$$

For example, the relationship (3) can be respecified to produce

$$x_{1,t} = (1 + a)x_{1,t-1} - x_{2,t} + u \tag{5}$$

where $x_{2,t}$ is the amount of urbanization at time t. The size of rural population depends on natural increase as well as the loss through urbanization.

Models of the fundamentalist type entail a number of problems making them difficult to evaluate and revise scientifically given the current state of the art. Two of these problems play an important role in our argument at a later point. One problem is that as the number of components and sufficiently strong connections among components increases the links between the structure and behavior of a model become increasingly obscured by complex interactions. At some point it becomes very difficult to attribute specific errors of fit between simulated and historical time series to specific aspects of the model's structure. Consequently, it becomes increasingly difficult to evaluate and revise the structure.

The other problem is that the data used as inputs to a model (values of initial conditions and parameters) and the historical time series data used to evaluate its outputs contain both systematic and random components. The former can be attributed to real world processes of the kind hypothesized in the model, and the latter to variables left out of the model, to stochastic factors, and to measurement error. As the number of components and interdependencies in a model increases, increasingly long sequences of calculations are required to deduce the behavior of the model, which may result in the cumulation of the random components in the input data.[9] In

[9] See William Alonso, "The Quality of Data and the Choice of Design of Predictive Models," in Urban Development Models (Washington, D.C.: Highway Research Board, Special Report 97, 1968), pp. 178-92. Alonso does not resolve the question of whether data errors cumulate in models with negative feedback mechanisms as well as other types of models.

any case, the larger the random components in either input data or historical time series data, the more difficult it is to attribute errors of fit to the structure of the model and consequently the more difficult it is to evaluate and revise the structure.

Strategies that are at least partially effective have been devised to cope with these problems.[10] For present purposes, however, it is sufficient to emphasize that the problem of achieving a scientifically productive confrontation between theory and data depends in large part on the size and connectedness of the model and the accuracy of the data.

The Connectedness of System Components

The model we use was designed to study the processes of modernization and mass politics in less developed countries, in particular Turkey and the Philippines. By modernization we mean primarily demographic and economic changes and changes in communications and transportation networks. By mass politics we mean political interactions among large aggregates of the population, not individual political actors. The aggregates defined in the model are the rural population, the urban population, the government, and (implicitly) the political opposition.

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[10] Aggregation, for example, tends to cumulate the systematic components of data and cancel the random ones. See G. U. Yule and M. G, Kendall, An Introduction to the Theory of Statistics (London: Griffin, 14th ed., 1950), p. 314. However, aggregation may increase the difficulty of choosing among alternative theories. See Guy H. Orcutt, Harold W. Watts, and John B. Edwards, "Data Aggregation and Information Loss," American Economic Review, Vol. 68 (September 1968), pp. 773-87.

The components of this model consist of the set of variables and parameters listed and defined in Table 1. They are grouped into three subsystems: the demographic subsystem which is relatively specialized to the growth and distribution of the population $N_{i,t}$; the economic subsystem which is relatively specialized to the production and distribution of economic goods $Y_{i,t}$; and the political subsystem which is relatively specialized to the production of changes in the size and distribution of mass support for the government $V_{i,t}$ and the determination of the size and distribution of government expenditures $G_{i,t}$. The variables in each subsystem are denoted by upper case letters and have time subscripts; the parameters are denoted by lower case Roman and Greek letters, and are assumed to be constant over time. Any component with an i subscript is disaggregated into rural (i=1) and urban (i=2) subcomponents, and has a rural and urban aggregate (i=3). Variables and parameters without i subscripts are defined only for the system as a whole, not the individual sectors.

Table 1

The Model's State Vector: Variables and Parameters

a. Demographic Subsystem

U_t = the number of migrants from rural to urban areas at time t.

$N_{i,t}$ = the population of sector i at time t.

s = the proportion of the participant rural population that would urbanize when economic performance in the two sectors is the same.

a_i = the rate of natural increase in sector i.

b. Economic Subsystem

$Y_{i,t}$ = gross product in constant currency for sector i at time t. Gross national product is the sum of gross product in the rural and urban sectors.

GR_t = total government revenue from all revenue generating schemes in constant currency.

$C_{i,t}$ = consumption in constant currency in sector i at time t.

$I_{i,t}$ = private investment in constant currency for sector i at time t.

$F_{i,t}$ = net foreign contribution to sector i at time t, aggregating the value in constant currency of both commodity trade and monetary transfers.

τ_i = the effective tax rate in sector i.

m_i = the proportion of per capita gross disposable income consumed in sector i. Gross disposable income in sector i is $(1-\tau_i)Y_{i,t}$.

r_i = the proportion of the change in per capita consumption which induces additions to (or deletions from) the previous level of investment.

c. Political Subsystem

$V_{i,t}$ = the proportion of sector i supporting the government at time t.

$G_{i,t}$ = government expenditures in constant currency in sector i at time t.

$D_{i,t}$ = government communications and transportation expenditures in constant currency in sector i at time t.

$P_{i,t}$ = the proportion of the people in sector i at time t that are participant.

$E_{i,t}$ = the expected rate of change in economic performance.

σ = the scale of fluctuations in support.

α_i = political penetration, or the proportional extent to which responses to economic performance in sector i are channeled through the government.

β_i = the relative preference of the government for sector i.

γ_i = the ratio of government communications and transportation expenditures in sector i.

δ_i = the communications and transportation expenditure in constant currency in sector i at which the communications and transportation system can be maintained with no appreciable effect on participation.

ε = the ratio of the change in the expected rate of economic performance to the difference between the actual and expected rates.

WINVOT = the proportion of aggregate support below which the government loses the election.

The relationships in the model are grouped according to subsystems and presented in Table 2. These relationships are hypotheses about the way in which each variable changes as a function of the others, with the magnitude of the changes being determined in part by the parameters. They have been derived from Daniel Lerner's theory of political participation,[11] some general theoretical work, and case studies of Turkey and the Philippines.

Using inputs reflecting the situation in Turkey in 1950 and in the Philippines in 1951, the model was operated for ten yearly cycles to produce simulated time series of the variables for each country. A comparison of these simulated time series with the available time series from Turkey and the Philippines revealed that the maximum discrepancy between simulated and historical data (expressed as a percentage of historical data) for any variable in any individual year was about 17 percent. Average discrepancies were less than 5 percent. In short, in terms of the specification of its relationships and its behavior, the model bears enough resemblance to Turkey and the Philippines in the decade of the 1950s to be useful as a means of illustrating our methodological points. Those interested in additional information about the selection of components, the specification of relationships, and the fit between simulated and historical time series are referred to our essay on the model and its applications.

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[11] Daniel Lerner, The Passing of Traditional Society: Modernizing the Middle East (New York: Free Press, 1964), Chapter 2.

Table 2

The Model's Set of Relationships

a. Demographic Subsystem

$$U_t = s\left(\frac{C_{2,t}}{N_{2,t}} \quad \frac{N_{1,t}}{C_{1,t}}\right)^{P_{1,t}} N_{1,t} \qquad (6)$$

$$N_{1,t} = \left(1 + a_1\right) N_{1,t-1} - U_{t-1} \qquad (7a)$$

$$N_{2,t} = \left(1 + a_2\right) N_{2,t-1} + U_{t-1} \qquad (7b)$$

b. Economic Subsystem

$$Y_{i,t} = C_{i,t} + I_{i,t} + G_{i,t} + F_{i,t} \qquad (8)$$

$$GR_t = \tau_1 Y_{1,t-1} + \tau_2 Y_{2,t-1} \qquad (9)$$

$$C_{i,t} = m_i \ (1 - \tau_i) \ Y_{i,t-1} \frac{N_{i,t}}{N_{i,t-1}} \qquad (10a$$

$$I_{i,t} = I_{i,t-1} \frac{N_{i,t}}{N_{i,t-1}} + r_i \left(C_{i,t} - C_{i,t-1} \ \frac{N_{i,t}}{N_{i,t-1}}\right) \qquad (11b$$

c. Political Subsystem

$$V_{i,t} = V_{i,t-1} + \alpha_i \sigma P_{i,t-1} \quad \left[(1 - V_{i,t-1}) \ V_{i,t-1}\right]^3 \left[\frac{C_{i,t}}{N_{i,t}} \cdot \frac{N_{i,t-1}}{C_{i,t-1}} - E_{i,t-1}\right] \qquad (12)$$

$$G_{i,t} = B_i \left[\frac{N_{i,T-1} V_{i,t-1} - \Delta(N_1 V_1)}{N_{i,t-1} V_{i,t-1} + N_{2,t-1} V_{2,t-1} - \Delta(N_1 V_1) - \Delta(N_2 V_2)}\right] GR_{t-1} \qquad (13)$$

where $\Delta N_i V_i = N_{i,t} V_{i,t} - N_{i,\ t-1} V_{i,t-1}$

$$D_{i,t} = \gamma_i G_{i,t} \qquad (14)$$

$$P_{i,t} = 1 - \left(\frac{\delta_i}{D_{i,t-1}}\right), \ P_{i,t} \geq P_{i,t-1} \qquad (15)$$

$$E_{i,t} = E_{i,t-1} + \varepsilon\left(\frac{C_{i,t}}{N_{i,t}} \ \frac{N_{i,t-1}}{C_{i,t-1}} - E_{i,t-1}\right) P_{i,t-1} \qquad (16)$$

$V_{i,t} = (1 - V_{i,t})$ If t is an election year and $V_{3,t}$<WINVOT (17)

The degree of connectedness or interdependence implied in the relationships themselves (as opposed to the degree implied by the operation of the model in each national context) can be explored by noting the presence or absence of causal links among the variables. Let us call this the structural connectedness of the model, which is summarized in Figure 1. The numerical entries in the cells of the matrix give the number of direct causal connections between the output (or row) variable and the input (or column) variable. Time subscripts have been ignored: Thus for purposes of assessing the structural connectedness of the model, a variable at t is equivalent to the same variable at t-1. Inspection of Figure 1 reveals that only 59 of 400 possible pairs of variables are directly connected.

This static description of the structural connectedness of the model underestimates the degree of connectedness among variables as the model operates through time. For example, as shown in relationship (9), since government revenue GR_t is merely a function of gross product in the rural and urban sectors, $Y_{1,t-1}$ and $Y_{2,t-1}$, variation in GR_t within one yearly cycle is limited to variation in these two variables. However, if the model is operated through time, the number of variables causally connected to GR_t increases. Thus while GR_t is a direct function of $Y_{1,t-1}$ and $Y_{2,t-1}$, as we have seen, it is also an indirect function through these two variables of $C_{1,t-1}$, $I_{1,t-1}$, $G_{1,t-1}$, $C_{2,t-1}$, $I_{2,t-1}$, and $G_{2,t-1}$; and through these variables, GR_t is an indirect function of several other variables, and so on. The causal chains of one, two, and three links connecting GR_t and these variables are diagrammed in Figure 2.

Figure 1

Structural Connectedness by Functional Subsystems

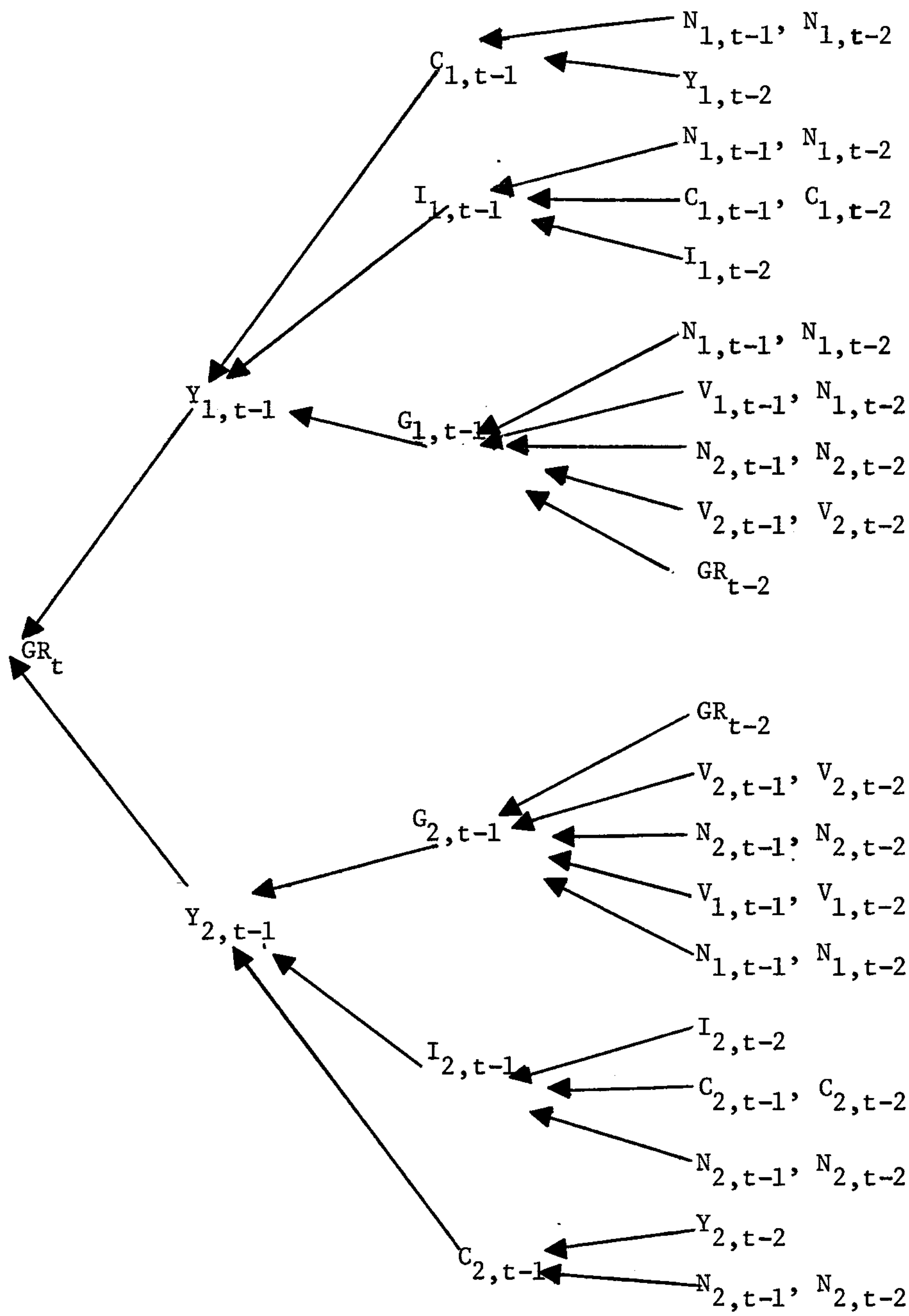
Inputs

Outputs		Demographic Subsystem			Economic Subsystem							Political Subsystem									
		U	N_1	N_2	Y_1	C_1	I_1	Y_2	C_2	I_2	GR	V_1	G_1	D_1	P_1	E_1	V_2	G_2	D_2	P_2	E_2
Demographic Subsystem	U	0	1	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
	N_1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	N_2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Economic Subsystem	Y_1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	C_1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	I_1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Y_2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0
	C_2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	I_2	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
	GR	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Political Subsystem	V_1	0	1	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0
	G_1	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0
	D_1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	P_1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	E_1	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
	V_2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1
	G_2	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0
	D_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	P_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	E_2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1

$F_{i,t}$, the net exogenous contribution to the economy of sector i at time t appears in (8), but has been deleted from this figure.

Figure 2

Causal Chains of One, Two, and Three Links Affecting Government Revenue GR_t



More generally, since each additional power of the connectedness matrix corresponds to one additional yearly cycle of the model, it can be shown that the operation of the model through time extends the length of indirect causal chains connecting any two variables and increases the number of indirect causal chains.[12] In precise terms the entry in the i-th row and j-th column of the n-th power of the matrix gives the number of causal chains of n links by which variable i is indirectly connected to variable j. (The fourth power of the matrix is given in Figure 3 as an illustration.) For this particular model, the increases are dramatic. While there are only 59 direct causal chains, there are 163, 459, and 1257 indirect causal chains of 2, 3, and 4 links, respectively. Furthermore, there are 3382, 9172, and 24,708 indirect causal chains of 5, 6, and 7 links, respectively. Of the 400 possible pairs of variables, only 16 pairs remain unconnected in the fifth power of the matrix, 2 in the sixth power, and none in the seventh power. In short, there is at least one indirect causal chain of seven links through which each variable as an output is affected by each variable as an input.

The analysis of structural connectedness has obvious implications for the chartist approach to projection. Leaving aside the issues of time constraints and policy purposes raised above, our analysis suggests that even in a system that is loosely connected in its static description, every variable in the system may ultimately depend upon every other variable as the system operates through time. A simple extrapolation of trends which ignores these dependencies may indeed be highly misleading.

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[12] See James S. Coleman, Introduction to Mathematical Sociology (New York: Free Press, 1964), pp. 444-7 on "connectedness" of structure.

Figure 3

Indirect Structural Connectedness by Functional Subsystems

Causal Chains of 4 Links:
Connectedness Matrix to the Fourth Power

Inputs

Outputs		Demographic Subsystem			Economic Subsystem							Political Subsystem									
		U	N_1	N_2	Y_1	C_1	I_1	Y_2	C_2	I_2	GR	V_1	G_1	D_1	P_1	E_1	V_2	G_2	D_2	P_2	E_2
Demographic Subsystem	U	8	15	15	3	5	1	3	5	1	3	3	0	2	4	0	3	0	0	0	0
	N_1	7	8	7	1	4	1	1	4	1	0	0	2	1	3	0	0	1	0	0	0
	N_2	7	7	8	1	4	1	1	4	1	0	0	2	1	3	0	0	1	0	0	0
Economic Subsystem	Y_1	8	18	10	3	10	4	1	7	1	1	2	2	1	6	2	2	1	1	2	2
	C_1	7	10	5	3	4	2	2	2	0	0	1	1	1	2	1	1	0	0	1	1
	I_1	7	15	6	3	6	3	1	3	0	1	1	1	1	3	0	1	0	0	0	0
	Y_2	8	10	18	1	7	1	3	10	4	1	2	1	1	6	2	2	2	1	2	2
	C_2	7	5	10	2	2	0	3	4	2	0	1	0	1	2	1	1	1	0	1	1
	I_2	7	6	15	1	3	0	3	6	3	1	1	0	1	3	0	1	1	0	0	0
	GR	8	8	8	3	4	2	3	4	2	0	2	1	0	2	2	2	1	0	2	2
Political Subsystem	V_1	11	26	8	5	11	3	1	4	0	2	3	4	4	8	4	2	0	0	0	0
	G_1	14	22	22	5	9	2	5	9	2	2	3	2	4	7	3	3	2	2	3	3
	D_1	4	7	7	1	5	1	1	5	1	0	1	1	1	4	2	1	1	1	2	2
	P_1	2	2	2	1	1	0	1	1	0	0	1	0	0	1	1	1	0	0	1	1
	E_1	7	16	7	3	6	2	1	3	0	2	2	2	2	4	1	2	0	0	0	0
	V_2	11	8	26	1	4	0	5	11	3	2	2	0	1	4	0	3	4	3	4	4
	G_2	14	22	22	5	9	2	5	9	2	2	3	2	4	7	3	3	2	2	3	3
	D_2	4	7	7	1	5	1	1	5	1	0	1	1	1	4	2	1	1	1	2	2
	P_2	2	2	2	1	1	0	1	1	0	0	1	0	0	1	1	1	0	0	1	1
	E_2	7	7	16	1	3	0	3	6	2	2	2	0	1	3	0	2	2	1	1	1

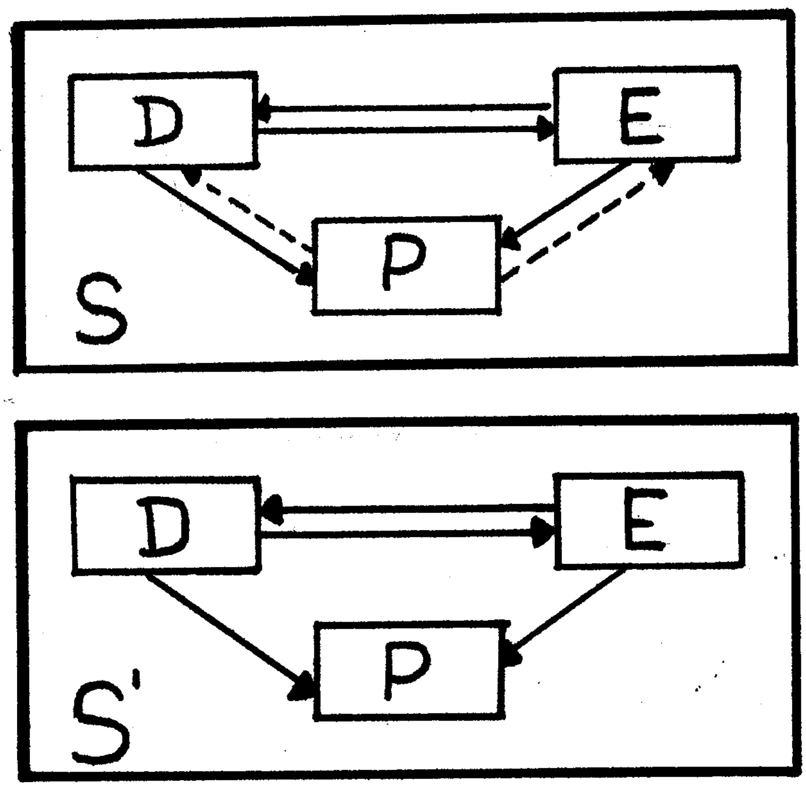
However, there is the possibility that in a particular system or in a particular application of the model, certain of these dependencies may be sufficiently weak that they can be safely ignored. If this were the case, the projections of the chartist who ignores these dependencies and of the fundamentalist who takes them more fully into account may be approximately the same. To consider this possibility, we must turn from the general structure of the model to its behavior in particular contexts, and to the results of the Ando-Fisher theorem on the decomposability of systems.

Decomposability of Systems

The Ando-Fisher theorem and related efforts deal with the general problem of determining the circumstances under which a system can be decomposed into its component subsystems for purposes of analysis. More precisely, consider a nearly decomposable system S in which one subsystem P is causally dependent on the rest of the system, but the rest of the system is only weakly dependent on the subsystem P. Consider also a decomposable system S' identical to S except that the weak causal dependencies from the subsystem P to the rest of the system are assumed to be absent. The nearly decomposable and decomposable versions of S are diagrammed in Figure 4, with the weak causal links indicated by the dotted line. Finally, let us define the relative behavior of the variables in P as their ratios. The result of the Ando-Fisher theorem is that for linear systems, the long-run relative behavior of the variables in P in the nearly decomposable system S and in the decomposable system S' is approximately the same, even though their behavior in terms of absolute levels and rates of change may be very different.

Figure 4

A Comparison of a Nearly Decomposable System S and a Decomposable System S



The weaker the weak dependency in S, the better the approximation. In short, to the extent that the chartist is dealing with a system that approximates the nearly decomposable system S, he may extrapolate relative trends in P and safely ignore the rest of the system.

Let us conjecture that the model of modernization and mass politics is a nearly decomposable system in which relative behavior in the political subsystems can be explored independently of the rest of the system. Let us also conjecture that the result of the Ando-Fisher theorem holds for this model even though the model is nonlinear. If the model is nearly decomposable as applied to the Turkish case, the Philippine case, or both, the ratios of the political variables over time generated by the complete version of the model should approximate the ratios generated by the decomposable version. To specify a decomposable version, we need only replace the variable $P_{1,t}$ in relationship (6) and the variables $G_{i,t}$ in (3) by constants equal to their initial values. These are, respectively, $P_{1,1}$ and $G_{i,1}$. With these modifications the urbanization and income relationships become

$$U_t = s \frac{(C_{2,t} N_{1,t})}{N_{2,t} N_{2,t}} \quad P_{1,1} N_{1,t} \qquad (6')$$

$$Y_{i,t} = C_{i,t} + I_{i,t} + G_{i,1} + F_{i,t} \qquad (8')$$

The results are presented in Table 3, where the degree of approximation is calculated as the difference between the relative behavior of the complete and decomposed versions expressed as a percentage of the relative behavior of the complete version. Perhaps the best approximation is in

Table 3

The Long Run Relative Behavior of a Model: Complete Version (CV) and Decomposed Version (DV)

a. Turkey

	$V_{1,t}/V_{2,t}$				$G_{1,t}/G_{2,t}$			
t	CV	DV	DIFF.	% DIFF.	CV	DV	DIFF.	% DIFF.
1950	1.000	1.000	.000	0.0	.509	.509	.000	0.0
1951	1.007	1.007	.000	0.0	.614	.614	.000	0.0
1952	1.063	1.023	.040	3.8	.575	.599	-.024	-4.2
1953	1.096	1.048	.048	4.4	.609	.591	.018	3.0
1954	1.142	1.081	.061	5.3	.609	.589	.020	3.3
1955	.956	.885	.071	7.4	.759	.725	.034	4.5
1956	1.048	.925	.123	11.7	.488	.477	.011	2.3
1957	1.040	.972	.068	6.5	.582	.482	.100	17.2
1958	1.079	1.029	.050	4.6	.539	.490	.049	9.1
1959	1.090	1.096	-.006	-0.6	.564	.504	.060	10.6
1960	1.106	1.175	-.069	-6.2	.555	.521	.034	6.1
1961	1.110	1.267	-.157	-14.1	.561	.544	.017	3.0
1962	1.110	1.373	-.263	-23.7	.556	.573	-.017	-3.1
1963	1.102	1.494	-.392	-35.6	.552	.607	-.055	-10.0
1964	1.090	1.632	-.542	-49.7	.543	.647	-.104	-19.2
1965	1.072	1.789	-.717	-66.9	.531	.693	-.162	-30.5

	$G_{1,t}/V_{1,t}$				$G_{2,t}/V_{2,t}$			
t	CV	DV	DIFF.	% DIFF.	CV	DV	DIFF.	% DIFF.
1950	1047	1047	0	0.0	2056	2056	0	0.0
1951	1052	1052	0	0.0	1725	1725	0	0.0
1952	1155	1165	-10	-0.9	2136	1992	144	6.7
1953	1197	1236	-39	-3.3	2155	2192	-37	-1.7
1954	1250	1304	-54	-4.3	2346	2395	-49	-2.1
1955	1662	1800	-138	-8.3	2094	2197	-103	-4.9
1956	1524	1698	-174	-11.4	3271	3293	-22	- .7
1957	1583	1765	-182	-11.5	2827	3560	-733	-25.9
1958	1652	1838	-186	-11.3	3309	3855	-546	-16.5
1959	1720	1905	-185	-10.8	3326	4146	-820	-24.7
1960	1803	1965	-162	-9.0	3591	4428	-837	-23.3
1961	1898	2016	-118	-6.2	3755	4691	-936	-24.9
1962	2009	2055	-46	-2.3	4009	4925	-916	-22.8
1963	2141	2079	62	2.9	4276	5120	-844	-19.7
1964	2305	2086	219	9.5	4623	5263	-640	-13.8
1965	2508	2072	436	17.4	5059	5346	-287	-5.7

Table 3 -- Continued

	$V_{1,t}/V_{2,t}$				$G_{1,t}/G_{2,t}$			
t	CV	DV	DIFF.	% DIFF.	CV	DV	DIFF.	% DIFF.
1951	1.021	1.021	.000	0.0	.292	.292	.000	0.0
1952	.996	.996	.000	0.0	.369	.369	.000	0.0
1953	.940	.975	-.035	-3.7	.303	.318	-.015	-5.0
1954	.905	.991	-.086	-9.5	.306	.299	.007	2.3
1955	.931	1.008	-.076	-8.2	.259	.286	-.027	-10.4
1956	.912	1.024	-.112	-12.3	.266	.276	-.010	-3.8
1957	.948	.970	-.022	-2.3	.232	.267	-.035	-15.1
1958	.939	.973	-.034	-3.6	.241	.242	-.001	-0.4
1959	.990	.973	.017	1.7	.212	.232	-.020	-9.4
1960	.983	.969	.014	1.4	.227	.222	.005	2.2
1961	1.055	1.033	.022	2.1	.197	.212	-.015	-7.6
1962	1.042	1.026	.016	1.5	.220	.217	.003	1.4
1963	1.146	1.017	.129	11.3	.184	.207	-.023	-12.5
1964	1.109	1.004	.105	9.5	.222	.197	.025	11.3
1965	1.268	1.011	.257	20.3	.172	.187	-.015	-8.7
1966	1.177	.995	.182	15.5	.237	.181	.056	23.6

	$G_{1,t}/V_{1,t}$				$G_{2,t}/V_{2,t}$			
t	CV	DV	DIFF.	% DIFF.	CV	DV	DIFF.	% DIFF.
1951	335	335	0	0.0	1171	1171	0	0.0
1952	375	375	0	0.0	1011	1011	0	0.0
1953	355	357	-2	-0.6	1101	1095	6	0.5
1954	379	388	-9	-2.4	1121	1287	-166	-14.8
1955	412	423	-11	-2.7	1480	1492	-12	-0.8
1956	447	462	-15	-3.4	1535	1714	-179	-11.7
1957	478	461	17	3.6	1948	1675	273	14.0
1958	515	493	22	4.3	2002	1978	24	1.2
1959	542	543	8	1.5	2524	2232	292	11.6
1960	582	576	6	1.0	2524	2513	11	0.4
1961	602	512	90	15.0	3228	2490	738	22.9
1962	647	558	89	13.8	3065	2642	423	13.8
1963	657	597	60	9.1	4088	2931	1157	28.3
1964	711	637	74	10.4	3552	3243	309	8.7
1965	703	644	59	8.4	5179	3476	703	13.6
1966	778	689	89	11.4	3869	3779	90	2.3

the behavior of $G_{1,t}/V_{1,t}$ in the Philippine application. The maximum error is 15 percent (1961) and the errors are all less than 5 percent over the first ten years. The worst approximations are in $V_{1,t}/V_{2,6}$ and $G_{2,t}/V_{2,t}$ in the Turkish application. Maximum errors are, respectively, 66.9 percent (1965) and 25.9 percent (1957); the approximations are particularly poor after the eleventh year in the former and the eighth year in the latter. In general, for each comparison of relative behavior there is a tendency for the approximation to be better in the short run than in the long run.

In terms of the choice between the chartist and fundamentalist approaches, is the complete model a nearly decomposable system in which the political subsystem can be isolated from the rest of the system for purposes of studying political trends? Lacking mathematical proof that the result of the Ando-Fisher theorem holds for this class of nonlinear model, the answer is not clear. If the result of the theorem does not hold, the errors may not be evidence of near decomposability or the lack of it, but irrelevant to the issue. If the result of the theorem does hold, then we have gained some information on its degree of near decomposability in the Turkish and Philippine cases; whether the degree of near decomposability is sufficient depends on one's time frame and margin of tolerable error. If these errors are within the limits of tolerable error for given purposes, the _ceteris paribus_ assumption is appropriate and the political system's behavior can be studied apart from the rest of the system. If these errors are not within aceptable limits, the _ceteris paribus_ assumption is inappropriate and the functional boundaries of the analysis must be expanded beyond the political subsystem to account for demographic and economic factors. For most purposes these errors seem to be rather large.

Whether complex real world systems are less connected in a structural sense or more nearly decomposable in a behavioral sense than the model we have used remains to be seen. (We would expect the opposite.) However, to the extent that these results from the model can be generalized, they must be discouraging to those who wish to extrapolate trends as a means of studying the future of political systems. Even simple systems which are only loosely connected in their static description are highly interconnected in their dynamic behavior. Furthermore, at least in this model, these interconnections appear to be sufficiently strong that errors are likely to arise if certain trends are separated from the rest of the system for purposes of analysis. Even though we must simplify complex systems in order to understand them, the kind of simplification typical of the chartist approach does not seem to be productive in an empirical sense.

Some Limitations

Computer simulation models, as we have seen, are relatively well-suited to the investigation of the complex interdependencies underlying the behavior of social and political systems. We should not, however, underestimate the limitations of computer simulation models, and in particular the problems of developing and using them for the study of policy and the future.

To make the present model a useful tool for policy and projections, it would have to be expanded to incorporate a number of phenomena that are empirically or normatively important. For example, the cybernetic, structural-functional, and political cultural approaches to the study of political systems suggest that processes producing changes in parameters are important in real world political systems over appropriate time spans, and should be incorporated into the model. These processes would be interpreted as second-order feedback mechanisms or as socialization and recruitment processes. Normative questions about the distribution of values suggest that the model should be disaggregated beyond a simple rural-urban division to investigate, say, inequality between the few wealthy landowners and the mass of the peasantry, or between urban classes. However, as we have seen, as a model's size increases it becomes more difficult to evaluate and revise scientifically. There is an important trade-off between the inclusion of additional phenomena to increase a model's potential realism, and the need to keep a model small for the purposes of testing it. Moreover, criteria of empirical and normative importance are apt to change over time.

Furthermore, for even a small model such as the one considered here, data tend to be incomplete and inaccurate. For example, we have no time series data on expected economic performance $E_{i,t}$ to compare with the time series generated by the model. For other variables such as consumption $C_{i,t}$ we have only national totals and no rural-urban disaggregation. Of the data we do have, there is reason to believe that much of it is inaccurate. Time series on Turkish government expenditures from different sources differ by as much as 33 percent in individual years.[13] Critics of Philippine

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[13] Compare the data in the Public Finances section of several United Nations Statistical Yearbooks (1956, pp. 525-6; 1960, p. 535; and 1966, p. 652) with data from the Turkish State Institute of Statistics.

national accounts have claimed that the level of private investment has been underestimated by as much as 40 percent.[14] More complete and accurate data are needed to conduct more than weak tests of the model and to increase the rate at which it can be improved.

Finally, some aspects of the behavior of real world systems, particularly the role of chance and individuals, cannot be adequately simulated. To be sure, we can incorporate stochastic factors into models and assess their impact on important outputs. In the final analysis, however, we cannot forecast the precise nature, magnitude, or timing of these factors. For example, in February 1959, an airplane carrying Prime Minister Menderes and fifteen other members of a Turkish delegation to London crashed. Fifteen were killed but Menderes walked away. "As a result of this escape, he was viewed as almost superhuman by many superstitious Turkish peasants. This considerably reinforced his already large peasant support...."[15] President Magsaysay of the Philippines was killed in a plane crash shortly before the election of 1957. His death drastically changed the national political situation and, among other things, reduced the level of popular support for his Nacionalista party. In each case an accident affected popular support,

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[14] Important contributions to the debate over Philippine national accounts are: Emmanuel Levy, Review of Economic Statistics on the Philippines, Interim Report (Manila: World Bank Resident Mission, 1964, mimeographed); Clarence L. Barber, "National Income Estimates in the Philippines," The Philippine Economic Journal, Vol. 4 (1965), pp. 66-77; and Ruben F. Trinidad, "Some Proposed Improvements in the Estimation of Capital Formation in the Philippines," The Statistical Reporter, Vol. 4 (April 1960), pp. 28-40.

[15] Walter F. Weiker, The Turkish Revolution, 1960-1961: Aspects of Military Politics (Washington, D.C.: Brookings Institution, 1963), p. 12.

a variable defined in the model, but it is inconceivable that such accidents could be adequately reproduced in the behavior of the model.[16]

Some Challenges Implied for the Scientific Study of Policy

Assuming that our scientific sensibilities prevent us from falling back on more prosaic methods of forecasting such as star gazing, gut inspection, and meditation, the importance of the trends-processes matter must be taken into account. Unfortunately, that matter is not isolated from several other related concerns, summarized here to indicate the magnitude of the challenges.

- How does one connect a model or forecasting enterprise to the concrete circumstances captured by its information base?
- How does one ease the communication burden between contingencies produced by the forecast and realities perceived by concerned decisionmakers? What observable impacts operate, in both directions?
- How does one emphasize the creative aspects of forecasting, no matter the technique employed, in hopes of expanding the attention and problem-solution spaces of policymakers? Alternatively, how does one avoid saddling policymakers with old mistakes and sterile response routines?
- How does one forecast with partial or even nonexistent data? Unless one unrealistically assumes prescience, there is no way to anticipate either a large number of potential choices or the policy instrumentalities that will in time confront and be available to decisionmakers. How then does one anticipate future data needs?
- How might forecasting be turned into an opportunity for self-observation and self-modification?

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[16] Cf. the following from Bertrand de Jouvenal, The Art of Conjecture (New York: Basic Books, 1967), p. 110: "...any systematic effort at forecasting must rest on the understanding of processes, and we would be fools not to devote ourselves to this task on the lame pretext that such understanding does not enable us to make complete predictions."

Partial answers to these difficult, though basic, questions are evolving in several settings. Present concern is more narrowly focused on citing several distinctions between the trend and process perspectives, but even here answers are far from clear cut.

Conclusion

Both timeliness and accuracy are important criteria for policy analysis and forecasting. The major advantage of the chartist approach is timeliness, and the major advantage of the fundamentalist approach is greater potential accuracy. However, the empirical limitations of model building are significant. Modeling is not a panacea, although when intelligently intermixed with other techniques, it is often better than might be anticipated.

An institutional framework is required if we are to begin the serious integrative and cumulative tasks implied in this discussion. Martin Shubik's proposal to link large data-processing procedures with models provides a means for making quick extrapolations of trends and for the more time-consuming task of improving the quality of models and supporting data.

Harold D. Lasswell's proposal to develop institutions called decision seminars is similar but more sophisticated.[17] The decision seminar is designed to track and measure social events; as a procedural matter, the experiential data collected are quickly and systematically tested against the current sets of verbal and formal models. In decision seminars, models

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[17] See Harold D. Lasswell, "Technique of Decision Seminars," Midwest Journal of Political Science, Vol. 4, No. 3 (August 1960), pp. 213-36; and Lasswell, "The Political Science of Science," American Political Science Review, Vol. 50 (December 1956), pp. 961-79.

and trend data are used to project the future course of events and to invent and evaluate alternative policies; normative judgments and scientific formulations are amended based on the mismatches that exist between them and the collected data. If we are unable to build entirely accurate scientific models, at least we can try to recognize and rectify our errors through techniques such as the decision seminar.

Brunner and Brewer

POLICY AND THE STUDY OF THE FUTURE:
GIVEN COMPLEXITY, TRENDS OR PROCESSES?

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