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THE DYNAMICS OF POLITICAL CHANGE

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Political change and development in third world nations has been characterized by violent upheavals and sudden major shifts in government policies. Examples of discontinuities in the process of political change abound. Iran, Nicaragua, Argentina, Chile, Uruguay are only a few of the countries that stand out on this score.

Existing empirical studies of political change and development have not been capable of a formal analysis of discontinuous political transitions. The mathematics of bifurcating processes and of catastrophe theory provides an appropriate framework for the analysis of systems with structural discontinuities. Also recent statistical developments now enable the estimation and testing of these types of models. (Cobb, 1978, 1981)

In this paper we propose a theory of political dynamics capable of explaining endogenously the abrupt political shifts experienced in the last decade by a majority of developing nations. Section I introduces the mathematical concepts required for the analysis. Section II presents a theory of political change. Section III contains a discussion of the estimation techniques. Section IV presents the data. Finally sections V and VI contain a discussion of the results.

I. BIFURCATING PROCESSES

Bifurcation models describe dynamic systems with the properties that multiple equilibria and discontinuous leaps among dynamic paths are inherent possibilities. The following discussion of bifurcating dynamic processes is partly a summary of a discussion that can be found in Varaiya and Wiseman (1981).

Consider the differential equation system:

$$y = g(y, a) \tag{1}$$

Where $y \in R^n$ is a vector of endogenous or state variables and $a \in R^m$ is a vector representing a set of environment variables. The elements of the environment consist of both control variables and uncontrollable exogenous forces. (In planning terminology, the vector "a" consists of instruments and exogeneous variables.) It is assumed that there exists a one-way causal relation from the environment to the state.

The trajectory of the state $y(t)$, $t \geq 0$ can be determined by integrating the differential equation (1) given the trajectory of the environment $a(t)$, $t \geq 0$, and initial conditions for y. When the environment is constant, $a(t) = a$, it is usually the case that the state variable converges to an equilibrium, y_e or:

$$\lim_{t \to \infty} y(t) = y_e \tag{2}$$

where

$$f(y_e, a) = 0 \tag{3}$$

If only one value of y satisfies equations (2) and (3) then the system has a unique equilibrium. If there are several values of y then the system has multiple equilibria. This latter possibility is inherent in the mathematical forms chosen for g(y, a) in bifurcation and catastrophe theories, and is, indeed, one of the strengths of this type of analysis.

A special class of differential equations is the class of gradient systems where g(y, a) takes the form:

$$y = g(y, a) = \frac{\partial F(y, a)}{\partial y} \qquad (4)$$

In gradient systems the trajectories follow the path of "steepest ascent (descent)." Catastrophe theory can be viewed as a special class of gradient systems in which y is of dimension R or R^2.

The purpose of Thom's (1975) work on catastrophe theory is to show that dynamic gradient systems that exhibit discontinuous changes can be reparametrized into one of seven canonical polynomial forms. These canonical forms are referred to as catastrophe manifolds. A castastophe manifold is defined by the set of equilibrium values of y for all possible values of a, or by g(y, a) = 0.

An example of a fold catastrophe, the simplest of the catastrophe manifolds, is presented below. The fold catastrophe manifold is described by equation (5).

$$g(y, a) = \frac{\partial F(y, a)}{\partial y} = y^2 - a = 0 \tag{5}$$

The function F(y, a) defines a family of functions whose solution properties change with the values of a. Since equation (5) is a gradient dynamic system it defines the set of all values of y that correspond to the extreme points of the family of functions defined by F(y, a).

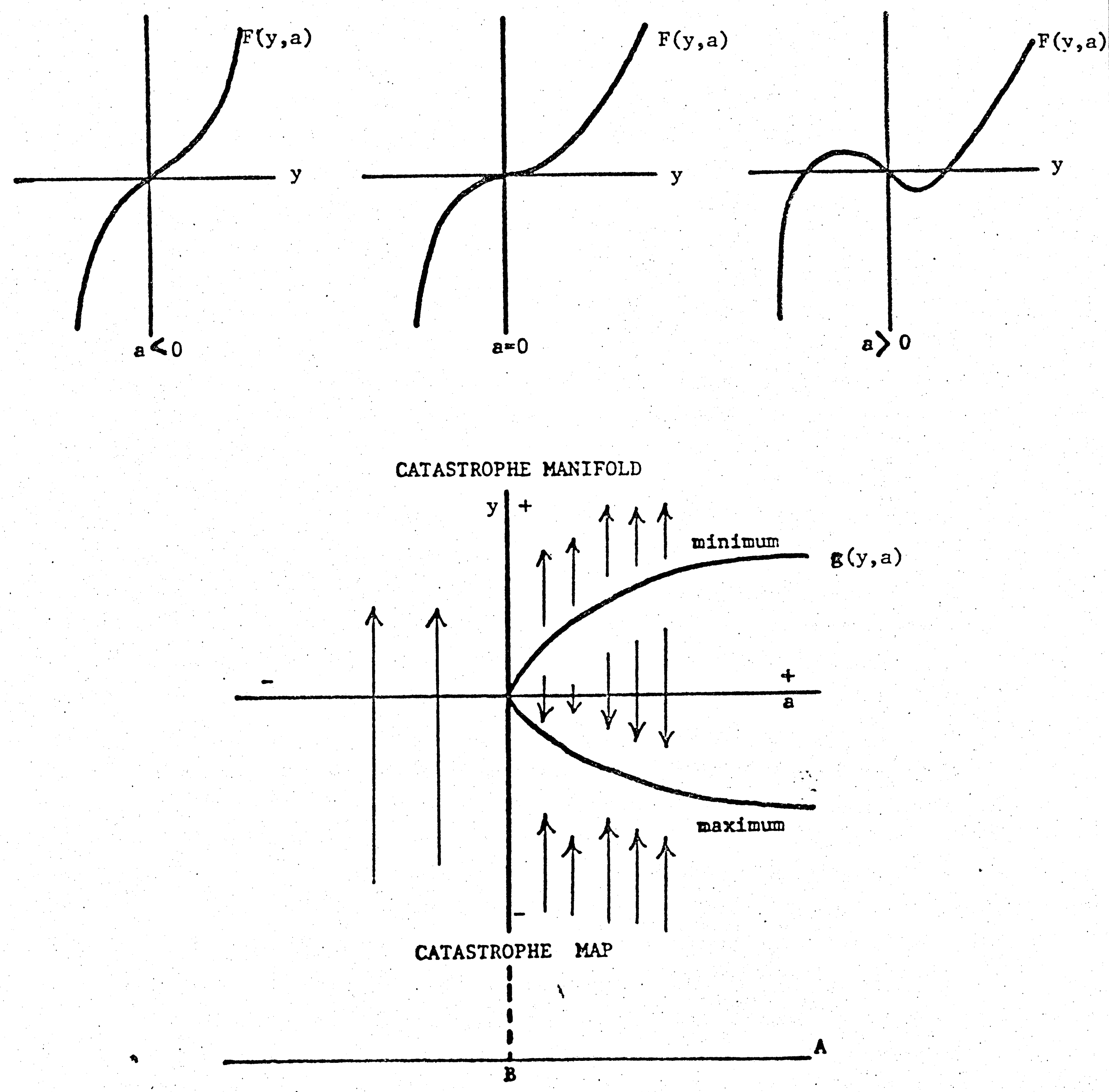
The graph of the family of functions that corresponds to the catastrophe manifold specified in equation (5), and the castrophe map are displayed in Figure 1. The state space is represented in this case by the vertical axis and the control space by the horizontal axis.

The catastrophe manifold is a parabola in y which shows that, corresponding to different values of a, there exist two critical points--one maximum and one minimum. When the control, a, is zero, the critical point is $y = 0$. This is a degenerate critical point because the second derivative is zero. If $a < 0$, then y^2 has no extreme points in the real plane. If $a > 0$, then we have $a = y^2$ and there are two symmetric values of y which satify the equation, namely, $y = \pm a$. When $y < 0$, F(y, a) reaches a maximum because the second derivative of F(y, a) is negative; and when $y > 0$, F(y, a) corresponds to a minimum because the second derivative is positive. The graphs in Figure 1 demonstrate how the underlying function changes as the value of the

FIGURE 1

FOLD CATASTROPHE

FAMILY OF FUNCTIONS



parameter changes. The bifurcation set is the set of points in the environment space that corresponds to degenerate extreme points. B is the bifurcation set. For the fold catastrophe, the bifurcation set consists of a single point. In this example, it separates the environment space into two spaces. One corresponds to the existence of two extreme points and the other corresponds to no points (see Figure 1).

The dynamics for the fold catastrophe (equation 2) are drawn on the catastrophe manifold in Figure 1 assuming the objective is to maximize equation 1. The maxima are only locally stable and for large values of y the system will converge to positive infinity.

In catastrophe theory it is usually assumed that the endogenous variable y moves very fast compared to changes in the control variable, a. Under the assumption of 'fast dynamics', the systems will always be close to the equilibrium trajectory which greatly simplifies the analysis.

II THE MODEL OF POLITICAL CHANGE

Recently third world politics have been characterized by a great deal of internal violence and by the emergence of numerous authoritarian regimes. The purpose of this paper is to propose a model for analyzing some of the economic, social, and political variables that have led to these political tendencies.

Classical modernization theory originally argued that economic development and social modernization would lead to equality, stability, and democracy. This theory was shown by events to be erroneous. Contemporary modernization theory states that only in the most advanced stages of development can one expect to find a high degree of correlation between economic development, equity, and political participation. Polarization of society and internal violence are not precluded at any point in the process of development, and their manifestations are very dependent on the specific set of growth and redistribution policies that are actually implemented [Adelman and Morris, 1973; Huntington, 1968; Feierabend, Feierabend, and Nesvald, 1969].

Classical Marxist theory emphasized class conflict as the moving force in politics and later, the role of international trade in promoting economic and political dependency. (Baran, 1957; Frank, 1969; Emmanuel, 1972).

Contemporary Marxists have dropped the idea that foreign capitalist expansion in a backward country inevitably leads to underdevelopment and have turned to an analysis of the historical diversity of interactions among external and internal influences in conditioning political and economic change. (Frank, 1979; Cardoso and Faletto, 1979).

Contemporary mainstream political scientists have advanced a variety of theories of change in the structure of political systems. Dahl (1971) discusses the forces which determine the likelihood of the formation of a stable, responsive political system (polyarchy). He argues that the existence of a stable polyarchy depends primarily on the historical sequencing of the emergence of political competition and political inclusiveness, and is conditioned by the existing socioeconomic order, the level of development, the degree of inequality, the beliefs of political activists, and the influence of foreign powers.

A bureaucratic authoritarian model (O'Donnel, 1973 ; Collier, 1979) has been advanced to explain the emergence in Latin America of military technocratic coalitions. In this model, as opportunities for profitable inport-substitution are exhausted, the ensuing slowdown in internal economic growth and balance-of-payments crises lead to bitterly disappointed political expectations among a growing educated technical elite. The technocrats then form a coalition with the military aimed at creating a climate favorable to both domestic and foreign investment and the furthering of industrialization. Finally, Galtung (1980) offers a change-agent theory of political and economic change. In his theory, groups or classes are ranked on three scales representing economic, political, and social status. The relative status or rank of a group may be the same on all three scales or it may differ from one scale to another. A group that does not have the same rank on all three scales is considered to be in rank disequilibrium. According to the theory, that group will attempt to achieve rank equilibrium and, in the process, will become an agent of change in the economic or political spheres.

While most of the above theories focus on the determinants of long run political development rather than upon abrupt short run shifts in political regimes, the variables and processes they discuss are also suggestive for a dynamic model of shorter run political change. In the following discussion, a model of the socioeconomic determinants of short run political change is developed that incorporates discontinuous shifts, bifurcations and multiple equilibria.

The endogenous variable y in the model, is intended to describe the major ideological orientation of the polity. In discussing the major political conflicts characterizing the political process in developing countries, Huntington and Nelson (1976) argue that the degree of emphasis on equity is a major element at all stages of development. At low levels of development the primary tradeoff is between the equalization of the distribution of income and political participation. At high levels of development the primary tradeoff is between growth and economic and political participation. Our indicator of the major ideological orientation of the polity is therefore defined as an index that is indicative of the degree of emphasis on equalitarian goals by the existing regime.

In each country, the regime in power is assumed to locally minimize a loss function that measures the distance between existing policies and the perceived underlying policy preferences. All governments, even the most authoritarian, require a measure of legitimacy to be able to function. This legitimacy derives from conforming to the norms of the poltical culture by which government structures, government policies and government performance are judged (Apter, 1972). The larger the distance between norms and policies, that is the greater the legitimacy gap, the less the credibility of the government and, hence, the less its efficacy for a given level of repression.

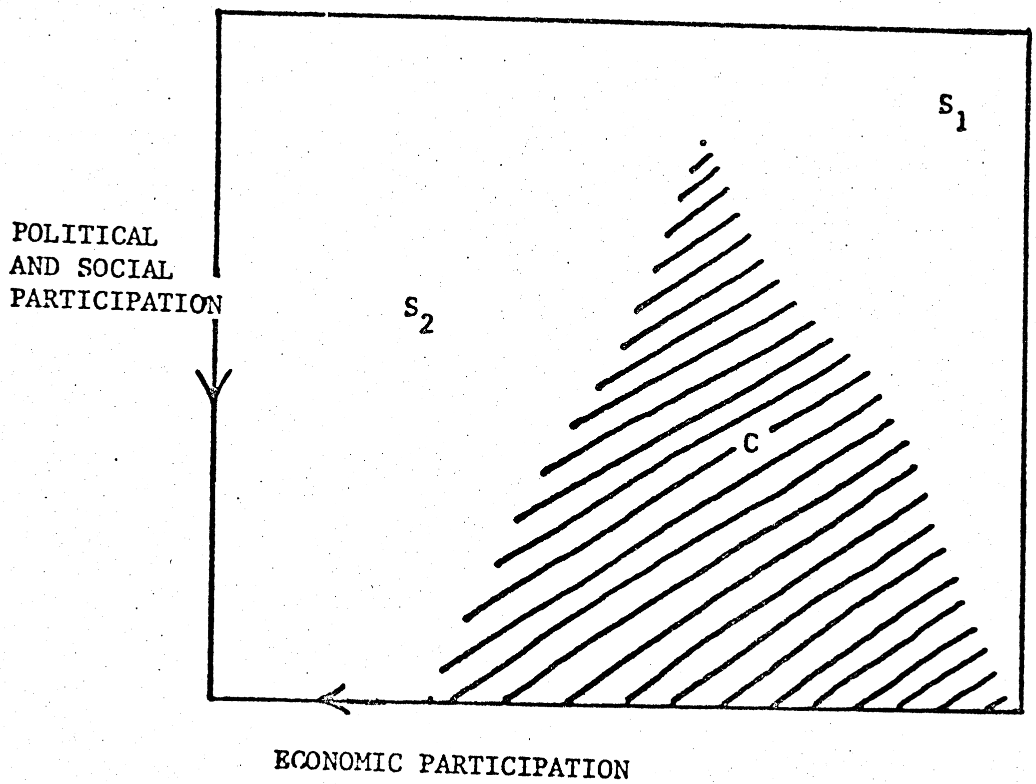
The norms of the political culture vary within and between countries. However, it will be assumed that in each country there exists a frequency function of policy preferences of the population which represents the distribution of the norms of the political culture within the citizenry. More specifically, the distribution of policy preferences indicates how the politically articulate population feels about the tradeoffs between redistribution and other policy objectives. This distribution of preferences can be either unimodal, indicating significant tendencies for social consensus, or bimodal, indicating substantial polarization. We shall assume that the specific shape of the preference distribution depends on the distribution of economic, social, and political participation in each country. In particular, Galtung's theory suggests that the distribution of policy preferences is likely to be unimodal under two distinct situations: Either economic, social, and political participation are concentrated in a small elite which, however, coincides with the politically articulate population or, alternatively, participation along all dimensions is widely shared. The distribution of preferences is likely to become multimodal when economic, social, and political participation are distributed inconsistently. By an inconsistent distribution we mean that different segments of the society are well rewarded in one or two dimensions of participation but not in all three. Those excluded will prefer more redistributive policies along the relevant dimension(s). Since the incidence of exclusion impacts differently on different social classes, multimodality of preferences may result.

It will be assumed that there exists an environment space which contains all possible combinations of economic, political and social participation. Figure (2) is one example of an environment space consistent with the preceding discussion. The shaded area, C, is the zone of polarization of preferences and would be where the preference distribution is bimodal. It corresponds to a moderate-to-poor distribution of economic participation combined with moderate-to-high levels of social and poltical participation. In this region there is a high likelihood that a portion of the educated, high-social-status population will be excluded from realizing economic rewards commensurate with its expectations. Those whose expectations are frustrated will favor more egalitarian policies, while those who are satisfied will favor continuation of existing policies. Thus, polarization of preferences is quite likely in this region. The relationship between polarization of preferences and significant policy changes and possible instability is very complex. We will discuss it in detail in section VI.

Outside of area C the distribution of policy preferences is likely to be unimodal. In the unshaded are, S_1, polarization will be unlikely because although economic participation is narrow, the number of educated is quite small and is also part of the socioeconomic elite. In the unshaded are, S_2, polarization will be improbable because

FIGURE 2

ENVIRONMENT SPACE



the distribution of economic participation is widely shared and economic, political and social opportunities are congruent.

The catastrophe manifold that corresponds to the catastrophe map that was defined in the above discussion of the environment space is a cusp catastrophe and is displayed in Figure (3). In the graph of the cusp catastrophe, the boundary of zone C is the bifurcation set. Zone C is the set of points in the environment space that corresponds to bimodal distribution functions. This is represented in the manifold by multiple layers above C. Outside of zone C, the distribution is unimodal; therefore, the manifold has only one layer and there is only one value of y that corresponds to an extreme point.

The cusp manifold of Figure (3) can be expressed mathematically, in canonical form, as:

$$g(z, a, b) = a + bZ - Z^3 = 0$$

where

$$Z = (y - l)/s$$

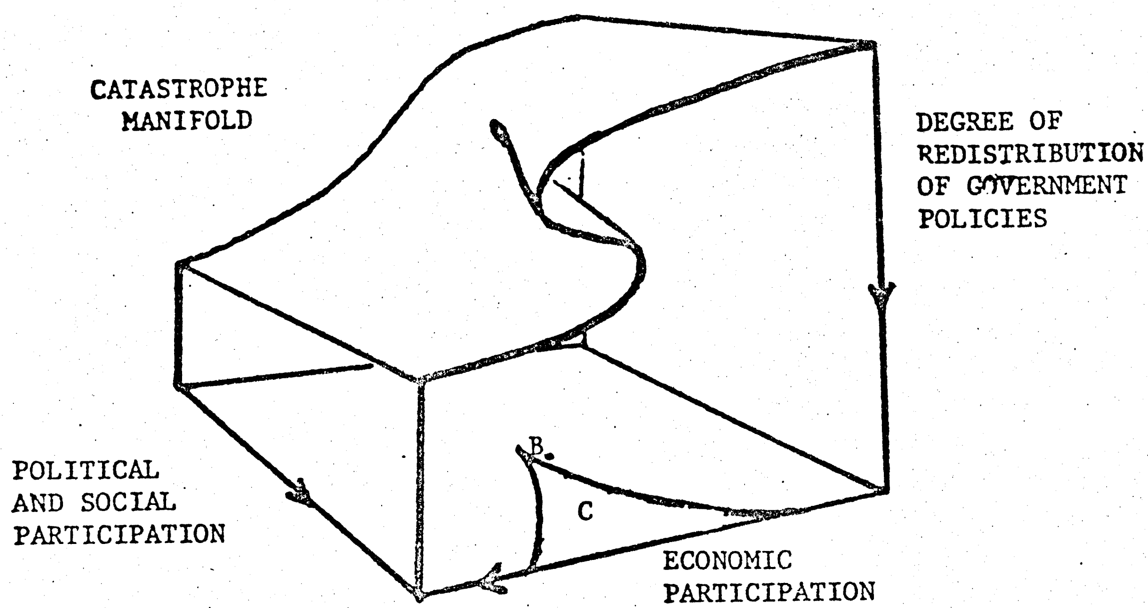
$$a = a_o + \Sigma a_i x_i$$

$$b = b_o + \Sigma b_i x_i \qquad (6)$$

The endogenous state variable y is the index of policy choice. The parameters l and s are the location and scale parameters which standardize y. There are two environment variables 'a' and 'b' which will be assumed to be linear

FIGURE 3

CUSP CATASTROPHE



functions of the ex ogenous variables x_i, i = i,v. Therefore, one must estimate 2·v + 4 parameters. The following section will summarize the procedure used for this estimation.

III STATISTICAL ESTIMATION AND INFERENCE

One of the principal criticisms levelled against catastrophe theory has been the lack of statistical verification of the existence of catastrophe manifolds. (For a more detailed discussion see Zahler and Sussman, 1977 ; Woodcock and Davis, 1978 ; and Poston and Stewart, 1978). However, as a result of some recent developments in mathematical statistics (Cobb, 1978, 1981) it has now become possible to estimate the parameters of a non-linear manifold. Standard estimation techniques fail because over some ranges of the exogenous variables multiple values of the endogenous variable are possible.

To carry out statistical estimation of the catastrophe manifold a random element must be introduced into g(y,a(x)). One useful formulation that arises in stochastic calculus (Soong, 1973) is to assume that

$$dy = g(y,a)dt + \sqrt{v(x)} \cdot dw(t) \qquad (7)$$

where dw(t) is a random input and v(x) is the limiting variance of the trajectories of y. In stochastic processes what is of interest is not the particular trajectory of the endogenous variable because there are an infinite number of such trajectories but, rather the distribution of the trajectory.

Cobb (1978) has developed an estimating technique for the parameters of the limiting distribution of the family of distributions represented by (7). The limiting distribution of the trajectory of y for the special case in which (1) the mean trajectory equals the deterministic part and (2) the limiting variance is constant is given by

$$\lim_{t \to \infty} f(y) = k \exp \int_y g(y,a)\, dy$$

(see Cobb, 1981).

For a cusp catastrophe this limiting distribution becomes

$$\lim_{t \to \infty} f(y) = k \exp (az + 1/2bz^2 - 1/4z^4) \quad (8)$$

where a and b are linear combinations of the exogenous variable and z is the standardized value of y. That is:

$$a = a_0 + \sum a_i x_i$$
$$b = b_0 + \sum b_i x_i$$
$$\text{and} \quad z = (y-l)/s$$

where l is a location parameter and s equals a scale paramater. The estimation of g (y,x,a,b,l,s) is then equivalent to the estimation of the parameters a_i, b_i, l, and s.

With some simple algebra it can be demonstrated that the above distribution function is a member of the standard exponential family of distributions (Lehman, 1959). For simplicity assume there is only one exogenous variable. Then the limiting distribution can be rewritten

$$\lim_{t \to \infty} f(y) = k \exp (c_1 y + c_2 xy + c_3 y^2 + c_4 xy^2 + c_5 y^3 - c_6 y^4)$$

Or more generally, it can be expressed as

$$k \exp [\Sigma c_i f_i(y,x)].$$

The maximum likelihood estimates of the parameters of such an exponential distribution exist and are unique (Crain, 1976), under very general conditions. However, the computations for obtaining the maximum likelihood estimates are quite involved and time consuming. As an alternative Cobb (1978, 1981) has suggested using the method of moments. It is this latter method that is used in deriving our estimates.

Parameter estimation employing the method of moments requires the ability to identify n linear equations in n parameters and n moments. Conceptually the idea underlying the method is that if enough of the moments of a distribution are known then the distribution can be specified exactly. Cobb (1981) shows that for distributions with the form $\exp(\Sigma c_i f_i(y,x))$ a system of equations can be derived relating n parameters to (2n-2) of the joint moments.

The method of moments provides a set of consistent estimates. This is the best one can hope for since the original parameters are non-linear functions of the c_i's. While an R-square type measure can be computed as an indication of goodness of fit, the method of moments does not permit parametric statistical inference because little is known about the statistical distribution of the parameters. We therefore use a non-parametric technique known as the Stone-Geisser method for statistical verification. (Stone, 1974, Geisser, 1974, 1975)

The Stone-Geisser method evaluates a model by measuring how well it predicts. The quality of the predictions is tested by removing one observation at a time from the data set, estimating the parameters, then measuring how well the left out endogenous variable is predicted. The prediction error is measured by the average squared deviations of the predicted from the actual values of the endogenous vairable. The ability to predict for several different models can be compared in this way. In our test, we compare the cusp model to a model which is linear in the same set of exogenous variables and that has been estimated by using ordinary least squares.

More formally, in the Stone-Geisser method the standard predictor for a linear model is $P_t = \bar{y} + (1-d)\,\beta^t (x_t - \bar{x})$ where P_t is the prediction for the endogenous variable in at time t, $\bar{y}$ is the mean of the endogenous variable, $\bar{x}$ is a vector of means of the exogenous variables, β^t is the vector of estimated coefficients and (1-d) is a weight placed on the least squares predictor which is selected by the modeler. The measure of the prediction error was defined so as to minimize $1/n\sum_i (y_i - \bar{y} - \beta^t_{.i}\,(x_i - \bar{x}))^2$ where $\beta^t_{.i}$ is the vector of coefficient estimators with the i^{th} observation removed. The weight (1-d) is small when the linear model is a poor predictor and has an upper limit of one when the linear model is a perfect predictor.

For the cusp model the predictor chosen is $P_t = d_{1t}r_{1t} + d_{2t}r_{2t} + d_{3t}r_{3t}$ where $d_{ji} = 0$ or 1 and $\Sigma_j d_{ji} = 1$. Hence in this case d becomes a selector while in the linear model it acts as a flattener. The r_{jt} are the predicted equilibrium positions for the state variable. The distance measure which is minimized over d_{ji} is $1/n \sum_i (y_i - \sum_j d_{ji} r_{ji})^2$.

IV THE DATA

In this model, a country at a single point in time is represented as a point in multiple dimensional space. All the data used for this study is ordinal and reflects economic, social and political conditions in the third world in the early 1960's.

The sample of countries consists of countries at a level of socioeconomic development corresponding to that of most of Asia and Latin America for which income distribution data for the sixties could be obtained. The data is presented in TABLE II.

The state variable, which is an index of the policy orientation of the regime in power, was constructed by the authors using the legislative policy information given in Countries of the World (1980), Encyclopedia Brittanica, and various contemporary history books. In determining a country's degree of redistributiveness a wide range of factors were considered. Countries considered to be highly non-redistributive had documented evidence of the economic exploitation of a significant segment of the population, and were heavily pro-growth. The most extreme example of non-redistributive countries in the sample are South Africa and Rhodesia. Countries considered to be highly redistributive had either had a major land reform in the last ten years or had an equitable distribution of land; and either actively pursued or allowed the formation of cooperatives or collectives or had nationalized some industries or both. The more extremely redistributive group in our sample is quite diverse including countries such as South Korea on the one hand and Egypt on the other. Naturally, most countries are somewhere in between.

The exogenous variables used as indices of economic, social and political participation are: the distribution of income and the degree of socioeconomic mobility, representing static and dynamic aspects of economic participation; the level of political participation; the level of education, indicating both the potential for political participation and an important ~~discussion~~ dimension of social participation; and a general variable which describes the country's overall level of socioeconomic development. Short definitions for these variables are presented in Table I, together with their sources. Extensive discussions of data sources and methods of classification are presented in the original studies (Adelman-Morris, 1967 and 1973). The data used in the analysis is presented in TABLE II.

TABLE I

VARIABLE DEFINITIONS AND SOURCES		
VARIABLE NAME	INDICATORS	SOURCE
Level of Education	Harbison-Meyer index which is a weighted average of secondary and high level enrollment ratios	Adelman & Morris 1967
Degree of Social Mobility	extent of access to education; access to middle class occupations; existence of cultural and ethnic barriers	Adelman & Morris 1967
Level of Socio-economic Development	Aggregate measured of indicators of economic, social and political modernization	Adelman & Morris 1967
Distribution of Income	Income share of poorest 40 percent of households	Adelman & Morris 1973 Jain, 1975
Extent of Political Participation	Extent that major cultural and ethnic groups have national political representation and actually participate in political institution and decision making.	Adelman & Morris 1973
Policy Index	Redistributive orientation of regime measured by emphasis on growth, formation of collectives, land reforms, nationalization of industries.	Constructed by Authors from Countries of the World (1980) and various sources.

TABLE II

SAMPLE DATA						
COUNTRY	POLICY ORIENTATION	LEVEL OF EDUCATION OF HOUSEHOLDS	INCOME SHARE OF POOREST 40 PERCENT	LEVEL OF SOCIOECONOMIC DEVELOPMENT	POLITICAL PARTICIPATION	SOCIAL MOBILITY
ARGENTINA	35	97	17.3	1.91	87	10
BOLIVIA	38	35	12.9	-0.35	62	20
BRAZIL	74	54	12.5	0.79	46	90
CHILE	53	90	15.0	1.39	90	80
COLOMBIA	41	54	7.3	0.66	78	90
COSTA RICA	35	90	13.3	0.78	90	90
ECUADOR	53	54	16.9	0.54	46	50
EGYPT	6	83	15.1	0.73	30	50
EL SALVADORE	74	41	12.3	0.71	46	50
GREECE	65	90	21.3	1.47	90	100
HONDURAS	62	35	7.3	0.26	70	20
INDIA	26	67	20.0	-0.28	81	10
IRAQ	22	60	8.0	-0.03	7	40
ISRAEL	10	97	16.0	1.77	90	100
JAMAICA	74	60	8.2	1.06	87	90
JAPAN	10	97	15.3	1.63	90	100
KOREA, SOUTH	10	90	17.7	0.85	46	90
LEBANON	53	54	7.2	1.44	64	90
MEXICO	35	60	10.5	0.75	87	80
PAKISTAN	86	60	17.5	-0.08	7	20
PANAMA	62	90	14.3	0.84	46	50
PERU	62	60	8.8	0.68	46	50
PHILIPPINES	74	97	12.7	0.56	78	80
RHODESIA	94	10	12.0	0.14	10	10
SOUTH AFRICA	94	83	6.1	0.62	10	40
SRI LANKA	26	60	13.7	0.35	78	80
TAIWAN	10	90	14.2	1.05	54	90
TRINIDAD AND TOBAGO	35	60	9.4	1.15	64	90
THAILAND	74	67	13.2	0.5	7	50
TUNISIA	14	41	10.6	-0.18	38	50
TURKEY	71	60	9.4	0.88	76	90
URUGUAY	53	90	14.2	1.59	90	100
VENEZUALA	35	90	13.4	1.37	90	90

V RESULTS - ESTIMATION

The results have some very interesting implications as to the courses of polarization, the relationship between polarization and instability, and for the prediction of short run political policy changes. In this section the results of the estimation will be discussed. The implicit dynamics will be analyzed in the last section.

Before presenting the estimates of the parameters, we shall discuss how the environment parameters determine the shape and position of the distribution of policy preferences. This discussion will provide a necessary background for understanding the country specific results in Table III and the implications for the individual country dynamics in the next section.

In Figure 4 are drawn six prototypical distributions of policy preferences corresponding to some of the combinations of the estimated values of 'a' and 'b'. From the figure it is readily apparent that the parameter 'a' of equation 3, which defines the cusp catastrophe, acts as an assymetry or skewing factor. When 'a' is negative the distribution of preferences is skewed to the left towards a policy orientation which emphasizes redistribution. When the factor 'a' is positive the distribution of preferences becomes skewed towards the right. The bifurcation factor 'b' determines when the distribution of preferences can be bimodal. A positive value of 'b' is a necessary but not a sufficient condition for bimodality. It is not a sufficient condition because when the absolute value of factor 'a' is big enough then a skewed unimodal distribution may occur even though 'b' is positive. This combination of values for 'a' and 'b' is not depicted separately; it would look like Figure 4a for a<<0 and 4c for a >0.

The estimates of the coefficients of the limiting distribution for the cusp manifold for our sample of developing countries are reported in Table III in standardized form. Standardization greatly simplifies the computations and makes the coefficients easier to compare. In unstandardized form the policy index has a location (l) of 48.46 and a scale (s) of 18.11.

The location parameter, l, combined with a=0 and b=0 defines the cusp point B_0 of the bifurcation set in Figure 3. For countries near the cusp point small changes in the parameters of the environment space can result in significant changes in the shape of the distribution of political preferences and also in sudden changes in system state. For our sample, the cusp point occurs at a value of the policy index which is politically dead center, neither noticeably redistributive nor noticeably non-redistributive.

FIGURE 4
DISTRIBUTIONS OF POLICY PREFERENCES
GENERATED BY A CUSP MANIFOLD

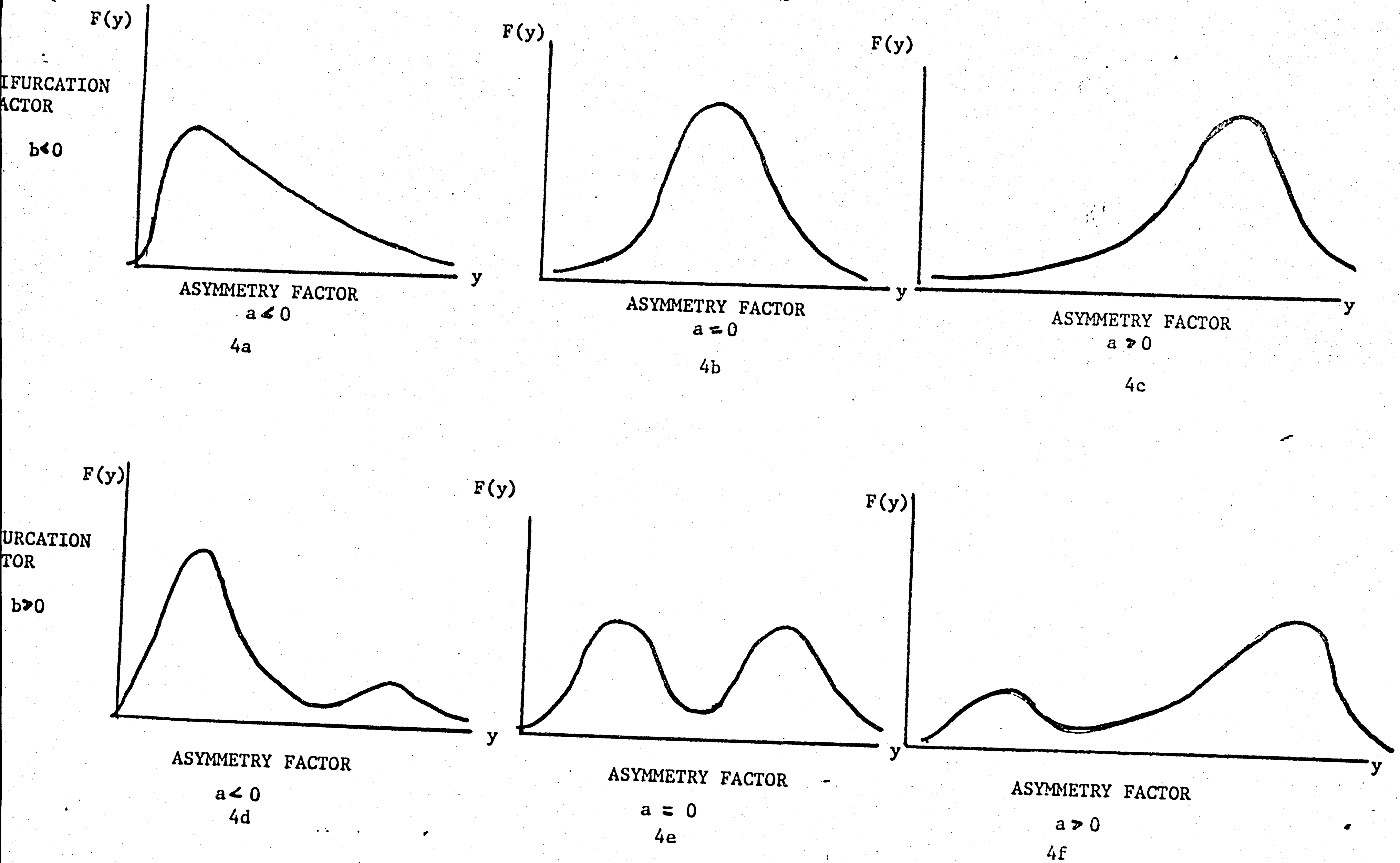


TABLE III

STANDARDIZED ESTIMATES OF THE ASYMMETRY AND BIFURCATION FUNCTIONS

VARIABLE	ASYMMETRY "a"	BIFURCATION "b"
Constant Term	-0.7541	2.3253
Education	0.2289	-0.1345
Income Distribution	-1.0539	0.4447
Socio-economic Development	0.3429	1.6519
Political Participation	0.3662	-1.8596
Social Mobility	-0.7323	-0.5791

From column 1 of Table III it is apparent that the greatest weight in determining the degree of asymmetry of 'a' goes to the distribution of income and to the extent of social mobility, which are measures of static and dynamic economic participation, and to the constant term. The coefficients of both variables determining 'a' are negative. This means that as economic participation increases there is an increase in preference for redistributive policies. Mathematically this is represented by the preference distribution becoming increasingly skewed to the left. The constant term which is also negative shows that the majority of developing countries in this sample and time period favored redistributive policies.

The bifurcation factor 'b' is primarily a function of the level of socioeconomic development, political participation and of the constant term. ~~The variables are opposing effects at work.~~ The largest parameter is the constant term which is positively correlated with the emergance of polarization. Therefore to be a developing country at that level of development is to face a high probability of being polarized. Further, as socio-economic development increases the chances that a country will become polarized increase even further. By increasing political participation, on the other hand, polarization can be reduced. It is interesting to note that education which has been so heavily criticized for creating political instability in developing countries does not appear as a very significant direct source of polarization.

As discussed in the previous section two measures of 'goodness of fit' are considred: an R-square type measure and a Stone-Geisser measure. An R-square of .688 was computed by choosing the predicted policy state closest to the observed[1]. The error sum of squares produced by the Stone-Geisser measure was .98 for the linear model and .75 for the cusp model. This difference is a 23.5% improvement. Since the range for the Stone-Gisser statistic is from 0 to 1 when the data has been normalized the linear model is almost the worst predictor possible.

In Table IV the predicted and actual policy states are displayed for each country along with each country's position in the (a,b) environment space.

With the information in TABLE IV we can classify countries into those that are expected to have few policy changes throughout the early and mid sixties and those for which we can expect significant policy changes. These classifications are displayed in Table V in the next section.

TABLE IV

MEASURED AND ESTIMATED VALUES OF THE POLICY INDEX, ASYMMETRY AND BIFURCATION FACTORS BY COUNTRY FOR 1960

Country	Policy	Asymmetry (a)	Bifurcation (b)	Mode 1	Trough	Mode 2
Argentina	35.00	-1.50	3.45	11.42	56.90	77.08
Bolivia	38.00	-0.56	0.19	32.14		
Brazil	74.00	-1.55	2.90	13.61	59.60	72.18
Sri Lanka	26.00	-1.41	-0.14	28.92		
Chile	53.00	-0.70	1.96	20.35	55.46	69.58
Colombia	41.00	0.24	-0.19	57.89		
Costa Rica	35.00	-0.83	-0.15	32.41		
Ecaudor	53.00	-1.91	3.51	10.39	59.53	75.47
Egypt	6.00	-1.21	4.71	7.03	53.18	85.18
El Salv.	74.00	-0.67	3.52	12.86	51.95	80.59
Greece	65.00	-2.91	2.53	12.31		
Honduras	62.00	1.46	0.72	72.84		
India	26.00	-1.66	-0.02	27.12		
Iraq	22.00	0.04	3.59	14.25	48.27	82.88
Israel	10.00	-1.19	2.70	15.30	57.14	72.95
Jamaica	74.00	0.40	0.41	65.15		
Japan	10.00	-1.07	2.23	17.82	58.61	68.96
Korea S.	10.00	-2.59	3.46	9.38		
Lebanon	53.00	0.54	2.92	19.36	45.08	80.95
Mexico	35.00	-0.17	0.01	38.28		
Pakistan	86.00	-2.13	4.96	4.67	56.58	84.14
Panama	62.00	-0.64	3.82	11.61	51.52	82.26
Peru	62.00	0.48	2.91	19.19	45.42	80.78
Phill.	74.00	-0.63	0.10	32.24		
Rhodesia	94.00	-0.70	5.24	5.83	50.90	88.66
S. Africa	94.00	1.23	4.86	11.07	43.83	90.49
Taiwan	10.00	-1.39	3.08	13.17	47.34	74.88
Thailand	74.00	-1.28	5.45	4.20	52.76	88.43
Tunisia	14.00	-0.82	1.35	23.25		
Turkey	71.00	-0.18	0.77	30.71	53.13	61.55
T and T	35.00	-0.18	2.32	20.18	49.88	75.34
Venezuala	35.00	-0.52	1.52	23.55	55.27	66.57
Uruguay	53.00	-0.86	2.03	19.44	57.14	68.81

As an example of how to read Table IV, consider Argentina, the first country in the table. As of 1960, the distribution of policy preferences in Argentina was bimodal. Argentina, therefore, had three possible equilibrium positions -- at each of the two modes and at the trough of the distribution. The asymmetry factor was -1.50, a moderately large negative value, so the distribution of policy preferences was skewed to the left, towards socialist policies. This means that the height of the mode at 11.42 (i.e. the preference for redistributive policies) was higher than that at 77.08, a strongly pro-growth position. In other words, the majority preferred strongly redistributive policies but there was a well defined minority with a strong pro-growth orientation. The bifurcation factor is 3.45 which means that the distance between the modes was fairly large and hence a substantial degree of polarization existed. Hence, the distribution of policy preferences was similar to that in Figure 4d. The measured index of policy choices at 35 was 12 units away from the predicted global equilibrium at 11 and hence Argentina appeared to be in a disequilibrium position. From Argentina's position on its preference distribution different statements can be made about the implicit future dynamics of its political change. These will be discussed in the following section.

VI IMPLICIT DYNAMICS

The dynamics outlined below are for the expected trajectories of a regime's policy orientation and therefore describe the latent tendencies for change which operate on the average for a country in a given position with a particular preference map. Repression, which is a systematic disturbance to the system, can be used to delay change from taking place, sometimes indefinitely, or to change the preference map by a change in participation.

We will now discuss the inherent dynamic tendencies that underly a system defined by $y = a + by - y^3$. Remember that the system is in equilibrium when y=0 which occurs at the extreme points of the distribution of preferences. There are two major classes of dynamics which need to be distinguished: changes in y that occur because the country's actual policies do not correspond to its equilibrium policies, as defined by its existing policy preference map. These changes are set in motion by political processes designed to increase the legitimacy of the government rather than by changes in the underlying preference map. The second class of dynamics occurs because of a shift in the preference map, occasioned by a change in the environmental parameters 'a' and 'b' and due to a change, systematic or unpredictable, in the exogenous participation variables x. In this case a country is likely to move from its previous actual position to the nearest equilibrium position on the new preference map. The shifts in the preference map itself can be either small or dramatic. Which it will be depends on precisely where on the manifold the country finds itself and whether a small or large change in the exogenous variables has taken place.

The possible changes in the distribution of policy preferences as a function of the country's location on the catastrophe map are graphed in the catastrophe map displayed in Figure (5). A country that is close to the boundaries of the bifurcation set can shift from a bimodal to a unimodal distribution or vice versa as a result of a relatively small change in the exogenous variables. On the other hand, a country with a small change in the exogenous variables well within the bifurcation set can shift from having a major mode corresponding to socialist policies to having a major mode that is, for example, bureaucratic-authoritarian, or it can continue to have a qualitatively similar preference map.

The dynamics we shall discuss in Table VI are of the "comparative statics' type. They will apply to either of two circumstances: no changes in the environmental variables or small changes in the environmental variables coupled with more rapid changes in the endogenous policy index. We shall illustrate the probable dynamics in Figures 6 and 7.

FIGURE 5
CATASTROPHE MAP WITH
FAMILY OF FUNCTIONS

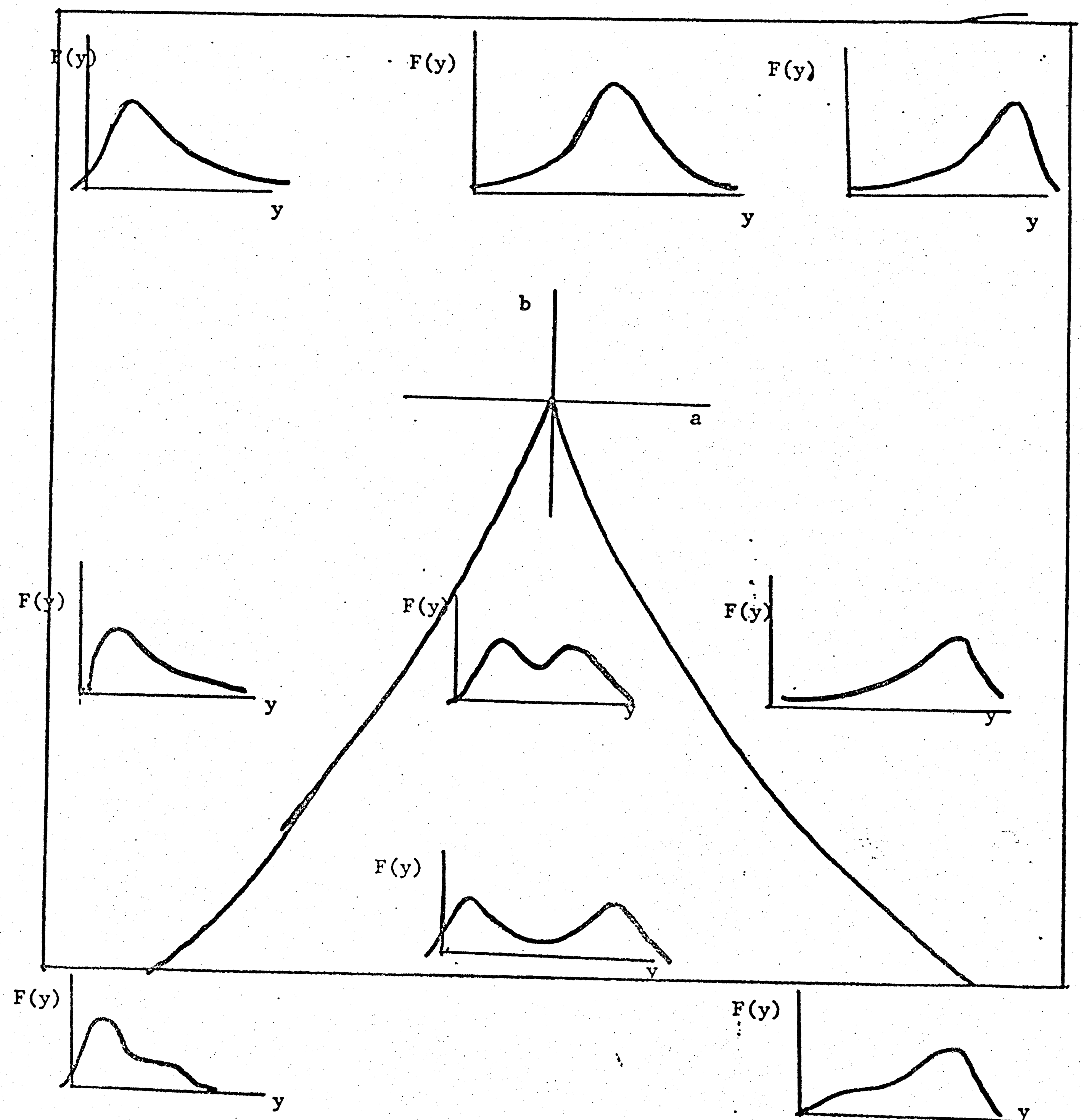


FIGURE 6
BIMODAL PREFERENCE DISTRIBUTION FUNCTION

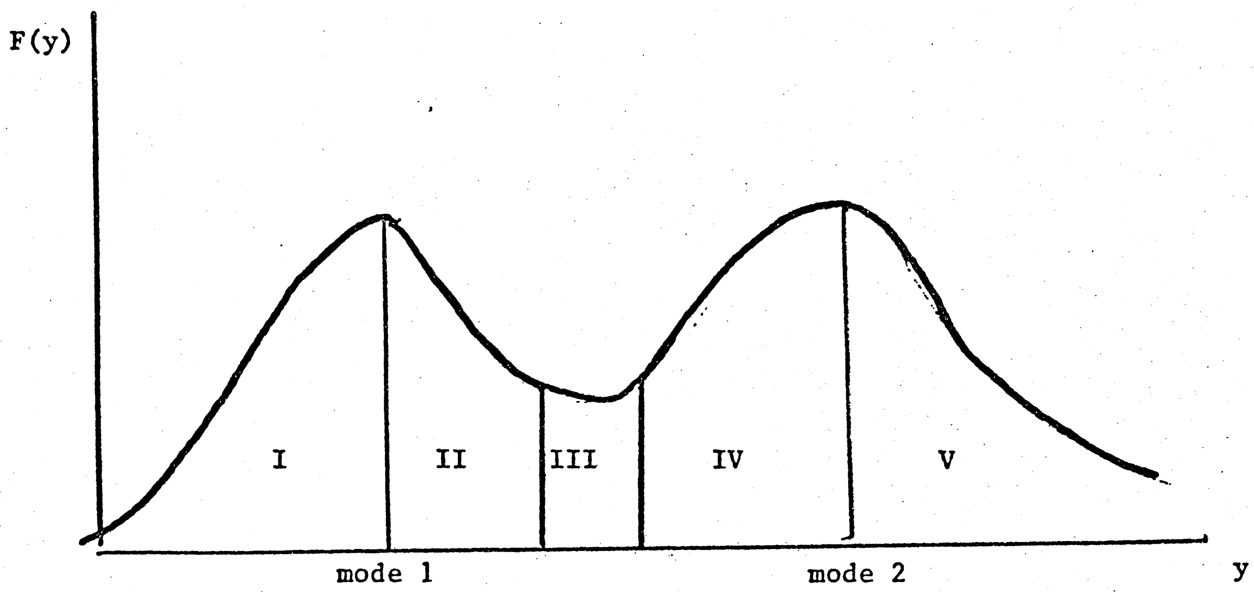


FIGURE 7
BIMODAL PREFERENCE DISTRIBUTION FUNCTIONS

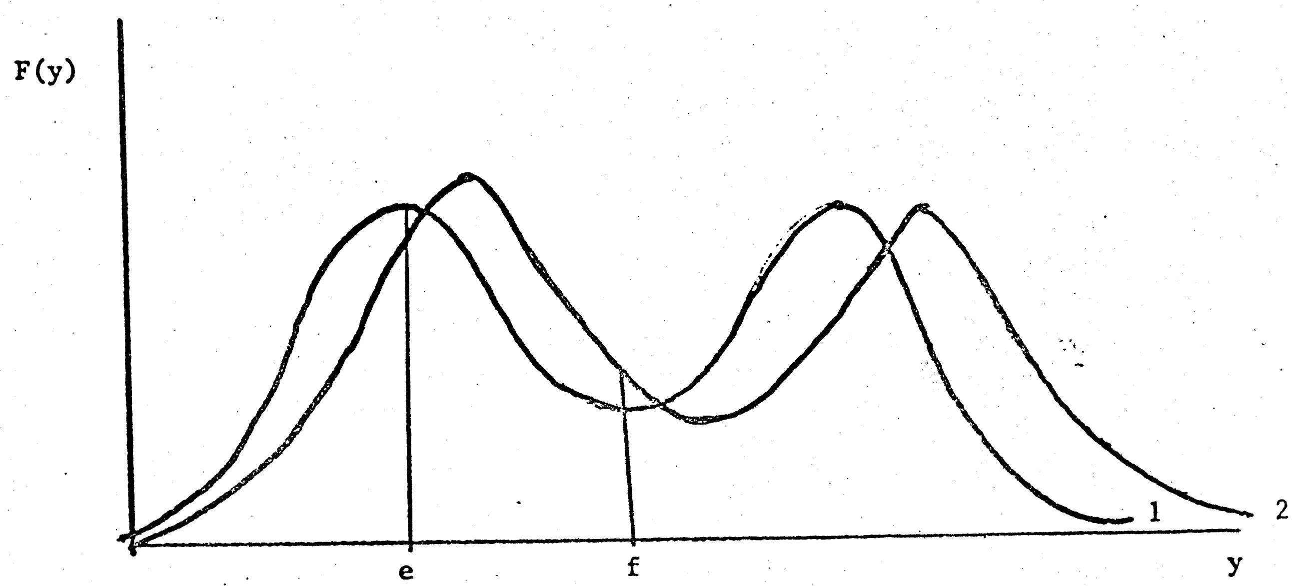


Figure 6 discusses state dynamics under unchanged environmental conditions. The distribution in Figure 6 is bimodal and therefore has two locally stable equilibria at the two modes and one locally unstable one at the trough of the distribution. The expected trajectory of policy choices, y, depends not only on the shape of the distribution of preferences but also on where the country is actually located on that distribution. For a country in zones I or II the expected trajectory is for policies to be brought into line with the equilibrium at mode 1. Countries near or at mode 1 may be driven away from 1 by random shocks to y but for a relatively large neighborhood the underlying dynamics are such that policies should eventually return to mode 1. This means that countries near the equilibrium point at mode 1 will only be found to have large changes in system state due to very large exogenous shocks to y, even when the underlying distribution of preferences is polarized. Hence polarization is not a sufficient condition for policy instability. Countries near the trough in Figure 6 in zone III, are at an unstable equilibrium in that small systematic changes in y can lead to a shift in policy towards either of the two modes. Mode 2 is another locally stable equilibrium. However its neighborhood of stability for the case drawn in Figure (6) is much smaller than for the first mode. This means that while a certain persistent tendency for policies to adjust towards mode 2 should be observed, moderate and large shocks to y should set forces in motion that will create a change in system state towards the global equilibrium at mode 1.

Clearly, there are several cases under which the potential for large changes in system state exists. The three cases for which the underlying dynamic forces leading to significant changes in policy choices are the strongest are: 1) countries near the trough in the distribution in zone III, from which they may move in either direction; (2) when the neighborhood for a local equilibrium is small; and (3) when policy choices are far from an equilibrium point. Countries far from an equilibrium will have strong systemic forces creating demands for rapid policy changes to drive the system to an equilibrium. This will be true even when the distribution of preferences is unimodal. Hence, polarization is neither a sufficient nor a neccessary condition for rapid policy change.

We now turn to a discussion of the expected dynamics under small changes in the environment space. These will lead to a change in the distibution of policy preference. In Figure 7 are drawn two possible distribution of policy preference. Assume a change in the environment occurred to cause a shift from distribution 1 to distribution 2. A country that was originally in equilibrium at point e would now find itself in a disequilibrium position that would require relatively small adjustement in policy to attain the new equilibrium position. On the other hand, a country at point f which was at an unstable equilibrium in distribution 1 in Figure 7 would suddenly find strong forces set in motion for a substantial change in policy.

The discussion of dynamics which is summarized in Table V is intended to apply to cases like those of Figures 6 and 7. That is, it applies to either no change in environment space or to only small changes in the environment space. Even when the change in the environment space induces a qualitative change in the distribution, the direction of policy change predicted by the model and its stability will be analogous to those in Table V as long as the change in the variables defining the environment space is small and the country is not at or near the cusp point.

It is not possible to discuss each country in depth so we will discuss only some of the more interesting cases along with some results that might appear to be questionable.

The most polarized countries in the sample are Thailand, Rhodesia, Pakistan, South Africa and Egypt. One interesting pair of countries is Rhodesia and South Africa. South Africa is correctly predicted to be stable throughout the sixties even though it is highly polarized because the existing highly non-redistributive policies were in line with the global equilibrium. By contrast Rhodesia's policies were in line with an equilibrium with only a small

TABLE V

UNIMODAL				BIMODAL			
COUNTRIES WITH NO MAJOR PREDICTABLE POLICY SHIFTS							
COUNTRY	APPROXIMATE DISTRI-TION	POSI-TION	EXPECTED CHANGES IN POLICY STATE	COUNTRY COUNTRY	APPROXIMATE DISTRI-TION	POSI-TION	EXPECTED CHANGES IN POLICY STATE
BOLIVIA	4a	II	MORE REDISTRIBUTIVE	EGYPT	4d	I	LESS REDISTRIBUTIVE
COLOMBIA	4b	I	LESS REDISTRIBUTIVE	IRAQ	4e	II	
COSTA RICA	4a	II	MORE REDISTRIBUTIVE	ISRAEL	4d	I	LESS REDISTRIBUTIVE
HONDURAS	4c	I	LESS REDISTRIBUTIVE	JAPAN	4d	I	LESS REDISTRIBUTIVE
INDIA	4a	I	LESS REDISTRIBUTIVE	SOUTH AFRICA	4f	V	MORE REDISTRIBUTIVE
JAMAICA	4c	II	MORE REDISTRIBUTIVE	TAIWAN	4d	I	LESS REDISTRIBUTIVE
KOREA, SOUTH	4a	MODE	NO CHANGE	TRINIDAD AND TOBAGO	4e	II	MORE REDISTRIBUTIVE
MEXICO	4b	I	LESS REDISTRIBUTIVE	TURKEY	4d	V	MORE REDISTRIBUTIVE
SRI LANKA	4a	I	LESS REDISTRIBUTIVE	VENEZUELA	4d	II	MORE REDISTRIBUTIVE
TUNISIA	4a	I	LESS REDISTRIBUTIVE				
COUNTRIES EXPECTED TO HAVE MAJOR POLICY SHIFTS							
OBSERVED POLICY STATES FAR FROM EQUILIBRIUM							
GREECE	4a	II	MORE REDISTRIBUTIVE	ARGENTINA	4d	II	INDETERMINATE
PHILLIPINES	4a	II	MORE REDISTRIBUTIVE	PANAMA	4d	IV	INDETERMINATE
				PERU	4f	IV	LESS REDISTRIBUTIVE
				ECUADOR	4d	III	INDETERMINATE
				LEBANON	4f	III	INDETERMINATE
				URUGUAY	4d	III	INDETERMINATE
POLICY STATE HAS A SMALL STABLE NEIGHBORHOOD							
				BRAZIL	4d	V	ALL OF THESE COUNTRIES MAY FIND LITTLE CHANGE HOWEVER SMALL SHOCKS CAN LEAD TO SUDDEN DRAMATIC CHANGES IN POLICY STATE.
				EL SALVADORE	4d	IV	
				PAKISTAN	4d	V	
				RHODESIA	4d	V	
EXTREME DEGREE OF POLARIZATION							
				THAILAND	4d	IV	INDETERMINATE

stable neighborhood. Further, it can be argued that in the past 20 years there have been changes in the environment parameters for South Africa so that the distribution of policy preferences has shifted and the present policies may no longer correspond to a global equilibrium position.

Chile and Uraguay are both in proximity to the trough for their respective distributions. Both countries have undergone dramatic changes in policies. However, as an example of the different possible trajectories, Chile has suffered violent and drastic changes among redistributive and non-redistributive policies while Uruguay has undergone a series of slow policy changes to become increasingly more non-redistributive.

El Salvador is an example of a country that went against the expected dynamics but with a very predictable result. El Salvador had a relatively symmetric but highly polarized distribution of preferences. In 1960, the closest stable point was to actually increase the non-redistributive policies of the existing regime. However, in 1960 there was a military coup to remove a conservative regime. In 1961 a moderate group was voted into power. Since that time there have been a series of policy changes to make the overall policy orientation increasingly more redistributive. Unfortunately by doing so the government moved to the trough of the distribution. It is now trying to protect its position with the use of substantial violence and repression.

VI CONCLUSIONS

This paper formulated a mathematical model of political change that incorporates, in vastly simplified form, the major ideas inherent in existing political science paradigms. The model was validated by using it to estimate the parameters of a catastrophe manifold and the individual political preference maps for the countries in the sample. The predicted dynamics are remarkably consistent with the subsequent political histories of the countries in the sample. We therefore feel that the model, though quite simple, may offer a vehicle for country risk analysis and for mathematizing some aspects of comparative politics.

The present study presents an initial exploration into the uses of bifurcation and catastrophe theory for explaining the socioeconomic origins of political instability. The results should be considered suggestive rather than conclusive. In general, it does appear that there exists significant empirical support for the theory proposed. However, more work needs to be done to validate the theory. Also, more experience with the use of catastrophe manifolds in the social sciences is needed to see whether they will prove to be useful tools for the anlysis of socioeconomic and political phenomena.

FOOTNOTES

1. Cobb argues that the trough in a bimodal distribution should not be included and therefore since the trough is unstable, one would not expect observations to be at the trough. Under that case the R-square becomes .476. It is not true however that no observations should be found near the trough. Hence Cobb's R-square measure is actually an understatement. The true value is somewhere in between .467 and .688.

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