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Summary

This paper presents a mathematical model of regime change in Latin America; the model is a finite Markov chain with stationary transition probabilities. A first-order Markov chain was found to fit the data satisfactorily, although there were indications that systematic biases existed. More sophisticated models which relax some of the assumptions of finite Markov chains may result in a better fit between model and data.

Regimes, Elites, and Regime Change

The unit of analysis used in this paper is the nation-state. Nation-states are considered to have one characteristic of importance in this analysis--regime type. Regime type is defined in terms of the elites that effectively control the government of a particular nation-state. The ruling elite may be a coalition of different civilian groups; it may be drawn from both civilian and military groups or the elite may be made up entirely of military men. We are concerned with the process of regime change over time, or the change (or absence of change) of elites in effective control.

If we consider elites to consist of two exclusive categories, civilian elites and military elites, then there are three logically exhaustive types: civilian regimes, mixed military-civilian regimes, and military regimes. If we further assume that it is impossible for civilian and military elites to cooperate perfectly in a mixed military-civilian regime we will find four different regime types: civilian regimes, civilian dominated military-civilian regimes, military dominated military-civilian regimes, and military regimes.

It is of interest to note that democratic regimes are a subset of civilian regimes; all other regimes in this classification system are authoritarian regimes.

We may generate some hypotheses about regime stability if we made some assumptions about the behavior of elites. We shall assume that civilian elites and military elites are both capable of functioning as the effective elite in a government. We shall further assume that military elites are not legitimate rulers until after civilian elites have been demonstrated to be ineffective rulers. In particular, civilian elites may lose legitimacy if they (1) fail to suppress domestic violence or (2) fail to react to clearly imminent threats to national security. (1) may be, of course, a subset of (2). Military elites may then intervene and take over effective control of the government. We shall further assume that military elites are unable to satisfactorily aggregate the demands of civilian groups and will eventually lose legitimacy, causing a reversion to a regime with civilian elites in effective control. The retention of civilians in a government dominated by the military would lead to more successful aggregation of the demands of civilian groups and result in a longer regime lifespan. Civilian regimes would have the longest lifespan of all, under this assumption.

The assumption that military elites only enter when civilian elites fail leads to the elimination of the civilian dominated military-civilian regime as a separate category. Such a regime could not follow a coup, as the military would demand effective control; in any other case it would be difficult, if not impossible, to distinguish such a regime from a pure civilian regime.

It should be noted that the transfer of power from a civilian regime to either a military-civilian regime or a military regime might occur voluntarily or involuntarily. A change in regime might occur after a coup, but a coup would not be necessary for a regime change.

We have therefore defined three types of regimes: (1) civilian regimes, (2) military dominated-civilian regimes, and (3) military regimes. From the discussion above we may derive the following hypothesis:

H1: The three regimes are ordered as follows in terms of stability over time: civilian, military-civilian, and military (military <u>least</u> stable).

The same discussion leads us to a second hypothesis regarding transition probabilities. We must expect that a nation-state which has shifted from a civilian regime to either a military-civilian regime or a military regime will return to a civilian regime first before moving to the other type of non-civilian regime. We would expect sequences of regimes of the following types:

(1) C-M-...-M-C

(2) C-MC-...MC-C

rather than

(3) C-M-...-M-MC

(4) C-MC-...MC-M

We therefore have the following hypothesis:

H2: The probability of a nation-state moving from a non-civilian regime at an arbitrary time t to a civilian regime at time t+1 is greater than the probability of the nation-state moving to the other type of non-civilian regime at time t+1.

A number of other hypotheses may be found if we look at the literature on regimes. There is not, at present, a substantial body of literature which empirically analyzes the nature of regimes and the process of regime change. Most of the literature which attempts to make cross-national comparisons is usually historical or descriptive rather than empirical. A good example of such a study is the work of Jose Nun (Nun, 1969); more recently, Alfred Stepan has presented as a hypothesis the emergence of a new type of military-dominated regime, the "New Professional" regime (Stepan, 1971; Einaudi and Stepan, 1971). Guillermo O'Donnell (O'Donnell, 1973) has presented another analysis, using both historical and empirical methods to analyze the authoritarian regimes of Brazil and Argentina.

The quantitative literature on political development is generally based on the assumption that political development is a process that covaries with economic development. This assumption is found in a wide variety of studies; among these are those of Lipset (Lipset, 1959), Lerner (Lerner, 1958), Cutright (Cutright, 1963), McCrane and Cnudde (McCrane and Cnudde, 1966), Flanigan and Fogelman (1971), and Pride (1971). In this paper "political development" is defined as a decrease in the probability of a nation moving from one regime type to another. This assumes that "political development" is synonymous with increased stability of regimes.

This literature does suggest the following hypotheses about regimes, and one set of hypotheses about the system of regimes. Before proceeding to list the hypotheses about regimes, a short digression about the assumptions of the cross-national method used in this paper seems important. There are two major assumptions--which may, in some cases, be testable assumptions--upon which the methodology of this paper is based. The first assumption is that of endogenous causation; the second assumption is that of cross-national comparability of units of analysis.

Endogenous Causation

There are two possible sets of variables, or factors, which could cause regime changes. It might be the case that regime changes were entirely due to endogenous factors; on the other hand, exogenous factors might combine with endogenous factors in determining regime changes. It is quite clear that exogenous factors alone cannot cause regime changes (if invasion is not included as a permissible cause). If causation is due to combined endogenous and exogenous factors we have a case of contagion, or "Galton's problem." For example, a coup d'etat in one nation might tend to trigger coups in other nations closely linked by geography, economic ties, or political ties. We therefore have the following assumption/hypothesis:

H3/A1: The causes of regime transitions are endogenous.

Comparability

The assumption of comparability is simply the assumption that the causes of the phenomena under investigation are common to all the individuals in our analysis set. Our individuals are nation-states; we are interested in the process of regime change over time. This assumption can be restated in the following way:

H4/A2: The probability of a nation-state with regime type i at arbitrary time t moving to regime type j at time t+1 is independent of the particular nation-state.

These two hypotheses/assumptions may be tested by using the transition probabilities and other statistics derived from the model to look at individual series of regime changes. We may find that the model derived from the aggregated data does not fit the individual histories of each nation-state; in that case, one of the two assumptions above has been violated. We call the propositions assumptions rather than hypotheses in this paper because the test provided by the model is rather weak. Since the propositions are not rigorously tested in this paper they will be considered assumptions rather than hypotheses.

The following set of hypotheses can be found in the literature mentioned above.

System Stability versus System Instability

If we look at the set of Latin American nations and the process by which these nations shift from one regime type to another we find two contrasting hypotheses. First, there is the hypothesis that the change from one type of regime to another is part of an orderly process; regime types follow each other in some pattern. The opposite hypothesis is that the process of regime change in Latin American nation-states is a chaotic process. It is difficult to distinguish between these two hypotheses at the level of the nation-state; at the level of the system of states, however, we would expect that the existence of an orderly process of regime change might result in a constant proportion of states of each regime type at all times; if the process were chaotic then there should be significant differences between the proportion of states of each regime type for different time periods. We therefore have the following hypothesis:

H5: The Latin American system of nation-states, as a system, is in a state of equilibrium.

Characteristics of Regimes

We have noted above that this paper looks at one characteristic of regime type--stability. We may therefore assume that this characteristic has or has not changed during the period 1946-66. This hypothesis is closely linked with the hypothesis concerning system stability. It is clear that if the stability of regimes has changed over the period 1946-66 then the system would also tend to be unstable; if this characteristic had not changed then the system would tend to be stable. We have, then, a final hypothesis:

H6: The probability of a nation-state with a regime type i at arbitrary time t having a regime of type j at time t+1 is independent of time.

This hypothesis deals with the "New Professionalism" thesis of Stepan. Stepan maintains that the requirements of modern warfare have led to the development of professional military elites which tend to view themselves as fully competent to rule the nation-state, and, when placed in power, tend to form military dominated regimes of much longer duration than was previously true. The two regimes discussed in particular are those of Peru and Brazil; Brazil's regime change took place in 1964, within the time period covered by this study; Peru's regime change took place after 1966; it is therefore not possible to directly test Stepan's hypothesis. Strong support for H6 would, however, tend to disconfirm the "New Professionalism" hypothesis.

We have made a number of assumptions about nations and the process through which those nations move from one type of regime to another. We have assumed that all the nations in the system are of the same type; we have assumed that the probability of moving from some regime i to some regime j, where i may equal j, is dependent only on the regime i. There is a class of mathematical models which are based on these assumptions, among others; these models are finite Markov chains. The use of Markov chains will also provide a basis for evaluating the other hypotheses mentioned above.

Markov Chain Models

This section is an elementary introduction to the theory of finite Markov chains. Those readers who already possess a knowledge of the subject may skip this section. Those readers desiring a more complete and rigorous treatment of the subject should consult Kemeny and Snell's text, Finite Markov Chains (Kemeny and Snell, 1960).

A Markov chain model is a model which describes a process. It is assumed that the process can take on a finite number of discrete states. These states may be defined as the set S:

$$S = (s_1, s_2, \ldots s_n)$$

The process consists of one or more individuals which move, in a series of steps, from some state s_i to some other state s_j; i and j may be identical. The process therefore occurs in discrete time; we observe the individuals at some time point t and count the number of individuals in each state at that time point; all the individuals either move to some new state or stay in the old state and we then again observe the number of individuals in each state at the new time point, time t+1. The probability of an individual moving from state i to state j when the individual is in state i at time t is defined as $p_{ij}(t)$.

The "Markov assumption" is that the probability of an individual moving from state i to state j at time t, or $p_{ij}(t)$, is dependent only on the state i. In a Markov chain, then, there is no memory of previous states held by individuals in the process.

A Markov chain model is said to be "stationary" if we assume that all the $p_{ij}(t)$'s equal some p_{ij}; in other words, the probability of going from state i to state j is independent of time.

We may represent the transition probabilities p_{ij} as a matrix with as many rows and columns as there are states. The entry in the ith row and the jth column is the probability of an individual moving from state i to state j in one step. This transition matrix is denoted by P^1, or more simply P. The transition matrix for a two-state Markov chain is given below:

$$P = \begin{array}{cccc} & & \multicolumn{2}{c}{\text{State at time } t+1} \\ & & s_1 & s_2 \\ \text{State at time } t & s_1 & p & 1-p \\ & s_2 & q & 1-q \end{array}$$

The sum of the probabilities of moving from one state to all other states must equal one; the row sums of P are necessarily one.

The distribution of individuals among the different states is denoted by a vector, Π_t; Π_t indicates the proportion of individuals found in each state s_i at time t. For example, if one-half of the individuals in the process are in each state of a two-state Markov chain at time 0 we have

$$\Pi_0 = \begin{array}{cc} (.5 & .5) \\ s_1 & s_2 \end{array}$$

The process is completely described if we are given both the initial vector Π_0 and the transition matrix P. The state of the process after one step can be found by multiplying Π_0 by P; after two steps by multiplying Π_0 by P^2 or P x P, and so on.

It should be noted that a Markov chain model is a stochastic model and not a deterministic model. The model does not tell us the state that a particular individual will be in after a series of steps; it will tell us the probability that a particular individual will be in a certain state after a series of steps. If we are given the distribution of individuals in each state at some time t we can find only the expected distribution of individuals in each state after an arbitrary number of steps. For example, if we have one individual in the process and the Markov chain is a two-state chain as given above, then the probability that the individual will be in either state, or Π_1 is

$$\Pi_1 = (1 \quad 0) \begin{pmatrix} p & 1-p \\ q & 1-q \end{pmatrix} = (p \quad 1-p)$$

It has been mentioned above that a Markov chain has no memory. A Markov chain can be endowed with memory if we redefine the transition probabilities. If we make the probability of an individual moving from state j at time t to state k at time t+1 a conditional probability dependent on the state i that individual was in at time t-1 (indicated by $p_{ijk}(t)$) we then have a memory of one time period. Such a Markov chain is called a second-order Markov chain. A second-order Markov chain may be converted to a first-order Markov chain, or a Markov chain with no memory, if we redefine the notion of "state." In a first-order Markov chain we are interested only in the state occupied by an individual at arbitrary time t; in a second-order Markov chain each state is an ordered pair of states from the first-order Markov chain; the first element is the state that the individual was in at time t-1, and the second element is the state that the individual was in at time t. For example, if we have a two-state process with states A and B we might see one individual pass through the following sequence of states:

AAABAAB

This series of observations would be converted to a second-order Markov chain with the following sequence of states:

(AA) (AA) (AB) (BA) (AA) (AB)

The transition matrix of a Markov chain with two states as a first-order chain has four states as a second-order chain, as there are four possible combinations of two things if order is important, i.e., AA, AB, BA, and BB. It should also be noted that there are some transitions that are forbidden in a single step. For example, an individual cannot go directly from (AA) to (BB) in one step; it is necessary to pass through an intermediate state (AB).

The transition matrix for a second-order Markov chain with two states in the first-order case is as follows:

$$\begin{array}{ccccc} & 11 & 12 & 21 & 22 \\ 11 & p & 1-p & 0 & 0 \\ 12 & 0 & 0 & q & 1-q \\ 21 & r & 1-r & 0 & 0 \\ 22 & 0 & 0 & s & 1-s \end{array}$$

The theory developed for first-order Markov chains may be applied to second-order Markov chains once the conversion has been made through the redefinition of states. The remainder of this section will therefore refer only to Markov chains in general; the chains may be of first or second order (actually, arbitrary order n).

There are two fundamentally different types of Markov chains. One type has some state i such that $p_{ii} = 1$ (and therefore all other p_{ij}'s are zero); this type of Markov chain is called an absorbing Markov chain. Once an individual enters such a state--called an absorbing state--the individual is trapped. If it is possible to go from any other state j to state i, the absorbing state, in a finite number of steps, then all the individuals in the process must end up in state i after a finite amount of time. There may be more than one absorbing state; in that case we would be interested in the probability of being absorbed in any particular absorbing state.

An absorbing Markov chain is composed of absorbing states and transient states; a transient state is a state which is not an absorbing or trapping state. There are a number of statistics that may be computed for an absorbing Markov chain; in particular, we can compute the mean number of steps before absorption given that the process starts out in a particular state; we may compute the mean number of times in each transient state given that we start out in a particular transient state; and finally, we may compute the probability of being absorbed by a particular trapping state given that we started out in a particular transient state.[1]

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[1] The transition matrix P of an absorbing Markov chain can be arranged so that it can be partitioned into four subsets by reordering the states. This partitioning is of the form

$$\begin{array}{c|c} I & 0 \\ \hline R & Q \end{array}$$

where I is a submatrix of P with k rows and columns, where k is the number of absorbing states; I is also an identity matrix. 0 is a matrix of zeroes, with k rows and n-k columns, where n is the number of states in the Markov chain. R is an (n-k) x k matrix; Q is an (n-k) x (n-k) matrix.

The matrix of mean times in each transient state given that the process begins in a particular transient state is given by

$$N_{(n-k)x(n-k)} = (I-Q)^{-1}$$

The matrix of variances of mean times in each transient state is given by

$$N2 = N(2N_{dg}-I) - N_{sq}$$

where $2N_{dg}$ is a matrix consisting of N diagonalized and with each element of the resulting diagonal matrix multiplied by 2, and N_{sq} is the matrix resulting from squaring every entry of N.

The vector of mean times before absorption is given by

$$\tau = N\xi$$

where τ is the vector of mean times before absorption and ξ is a column vector with all entries 1.

The matrix of probabilities of ending up in a particular absorbing state, given that the individual starts out in a particular transient state, is given by

$$B = NR$$

where B is the matrix of probabilities and N and R are as described above.

The second type of Markov chain has no absorbing states. A particular class of this type is a Markov chain in which it is possible to go from any state i to any other state j in a finite number of steps; in other words, some finite power of P has no zero entries. This class of Markov chains is called regular Markov chains.

A regular Markov chain has the property that the probability of an individual being in a particular state converges to a stable vector Π_s as time increases; in other words, the process converges to a steady state. This vector, Π_s, is the vector such that

$$\Pi_s \times P = \Pi_s$$

We may compute from the transition matrix P of a regular Markov chain a number of statistics; the most important is the matrix of first passage times which gives us the expected number of steps for an individual starting in state i to first enter state j.[2]

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[2] The stable vector Π_s may be computed in a number of ways; the easiest way, if a computer is available, is to take P and raise it to higher and higher powers until the rows converge. The matrix composed of rows which are the stable vector Π_s is called A.

The fundamental matrix for ergodic (and therefore regular) Markov chains is Z, computed as follows:

$$Z = (I - P + A)^{-1}$$

The matrix of mean first passage times, M, is computed as follows:

$$M = (I - Z + EZ_{dg})D$$

where E is a square matrix with all entries 1, Z_{dg} is Z diagonalized, and D is $(A_{dg})^{-1}$.

Parameter Estimation, Statistical Tests, and Goodness of Fit

The first step in applying Markov chain models to a data set is that of estimating the transition matrix P. Anderson and Goodman (Anderson and Goodman, 1957) have shown that the maximum likelihood estimator (MLE) for $p_{ij}(t)$ is

$$p_{ij}(t) = \frac{n_{ij}(t)}{n_i(t-1)}$$

where $n_{ij}(t)$ is the number of individuals in state j at time t and state i at time t-1, and $n_i(t-1)$ is the number of individuals in state i at time t-1. The MLE for p_{ij} is, similarly,

$$p_{ij} = \frac{\sum_{t=1}^{T} n_{ij}(t)}{\sum_{t=0}^{T-1} n_i(t)}$$

where time runs from 0 to T.

Once we have estimated P we may then compute the statistics discussed above. Before computing these statistics, however, we must test our model to see if a Markov chain model is a good fit to the data.

We may first test the hypothesis that the data is best accounted for by a second-order Markov chain against the hypothesis that the data is best accounted for by a first-order Markov chain. One statistic for this purpose is given by Anderson and Goodman and is used in this paper:

$$\chi^2 = \sum_{i,j,k} n_{ij}(p_{ijk} - p_{jk})/p_{jk}$$

where p_{ijk} and p_{jk} are estimated as above, and n^*_{ij} is the sum over k of n_{ijk}. χ^2 in this case has $m(m-1)^2$ degrees of freedom.

We may also test the hypothesis that the transition probabilities are constant over time. One test given by Anderson and Goodman is not well defined if any of the $p_{ij}(t)$'s are zero; the alternate test is based on constructing a contingency table for each row and then summing the resulting values; the computational formula is

$$\chi^2 = \sum_{i,j,t}^{m,m,T} n_i(t-1)(p_{ij}(t) - p_{ij})^2 / p_{ij}$$

which has m(m-1)(T-1) degrees of freedom. We may also test the hypothesis row by row by not summing over t; the resulting statistic has m(m-1) degrees of freedom.

If our model has survived these tests we then put it over more hurdles. We use the goodness-of-fit test described by Anderson and Goodman, which tests the hypothesis that p_{ij} is equal to p°_{ij}, j=1,...,m, where m is the number of states. Under the null hypothesis the statistic

$$\chi^2 = \sum \frac{ni^* (p_{ij} - p^{\circ}_{ij})^2}{p^{\circ}_{ij}}$$

$$\text{where } ni^* = \sum_j nij$$

is asymptotically distributed as chi-square with m-1 degrees of freedom. This test assumes that the p_{ij}'s are non-zero. We may use this test to test the hypothesis that the distribution of individuals among states in the observed vector is not statistically different from the stable vector; this test may be applied to the distribution over all time periods or it may be applied time period by time period. We may also compute the expected transition probabilities for two or more steps and compare the expected transition probabilities with the observed probabilities. If the model passes these tests, then we look at the pattern of residuals when the observed transition probabilities are subtracted from the expected transition probabilities. A systematic pattern here indicates a problem with the model, even if the fit is good by the chi-square goodness of fit test.

If our model is still satisfactory, we may make a weak check of the consistency of the model with each individual's sequence of states by comparing the observed first passage times with the expected first passage times. The expected first passage time is mean number of steps for an individual to go from state i to state j. In footnote 5 we gave the computational formula for M, the matrix of first passage times. Kemeny and Snell also give us the computational formula for the matrix of variances of first passage times, W; any observed first passage time that was more than two standard deviations (in absolute value) different from the expected first passage time would indicate a poor fit. The test is weak, however, as the standard deviations of the first passage times are very large; in most cases the standard deviation is greater than the number of years in our sample in this particular analysis.

If our model has come this far we may use the statistics computed from the transition matrix P. All of the models tested in this paper are regular Markov chains; we may make use, however, of the properties of absorbing Markov chains to discover differences between the various states. We may set some state or states to be trapping states; the theory of absorbing Markov chains, discussed above and in footnote 4, then tells us the mean number of steps for an individual to go from some non-trapping state to the trapping state, the variance of that mean, the mean number of times in each non-trapping state, and the probability of being trapped in a particular trapping state. In terms of our three-state theory of regimes we could find the mean number of years for a civilian regime to become a non-civilian regime, the variance of that number, and the probability of ending up as either military-civilian regime or a military regime. This assumes, of course, that we make military-civilian and military regimes into trapping states. If we reverse the assignment of trapping states and make civilian regime a trapping state we may then find out something about the relative stability of military-civilian and military regimes.

Operationalization and Source of Data

This paper has a major problem which it shares with many others: it was impossible to collect data independently for this paper. The availability of regime data from the *Cross-Polity*

Time Series data file (Banks, 1971) dictated the operational definitions used in this analysis. The definitions, as supplied by Banks[3] are as follows:

(1) Civilian. Any government controlled by a non-military component of the nation's population.

(2) Military-Civilian. Outwardly civilian government effectively controlled by a military elite. Civilians hold only those posts (up to and including that of Chief of State) for which their services are deemed necessary for successful conduct of government operations. An example would be retention of the Emperor and selected civilian cabinet members during the period of Japanese military hegemony between 1932 and 1945.

(3) Military. Direct rule by the military, usually (but not necessarily) following a military coup d'etat. The governing structure (author's emphasis) may vary from utilization of the military chain of command under conditions of martial law to the institution of an ad hoc administrative hierarchy with at least an upper echelon staffed by military personnel.

(4) Other. All regimes not falling into one or another of the foregoing categories....

Banks notes that the variable was collected for December 31 of each year. The regime typed ascribed to a nation-state is, therefore, the type of regime governing that nation of December 31 of that year and not a measure of the type of regime which predominated during that year.

The Banks file contains data on 19 Latin American nations from 1946 to 1966, 399 observations in all.[4] There are no missing data points.

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[3] Arthur S. Banks, Cross-Polity Time Series Data, (Cambridge, MIT Press - 1971), p. xv.

[4] Argentina, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela.

Data Analysis

The data were analyzed in two different ways. Separate analyses were run using both three-state data and two-state data. The two-state data set was constructed from the three-state data set by aggregating the "military-civilian" and "military" states together. Transition matrices and stable vectors for the first-order two- and three-state Markov chain models are contained in Table II.

TABLE II

First Order Markov Chain Models

Two-State

Transition Matrix

	s_1	s_2	
s_1	.948	.052	1 = Civilian
s_2	.286	.714	2 = Military-civilian + Military

Stable Vector

s_1	s_2
.845	.155

Three-State

Transition Matrix

	s_1	s_2	s_3	
s_1	.948	.028	.025	1 = Civilian
s_2	.256	.692	.051	2 = Military-civilian
s_3	.353	.176	.471	3 = Military

TABLE II (Continued)

Stable Vector

s_1	s_2	s_3
.845	.105	.050

The second order Markov chains are not shown here, as they were soon eliminated from the competition. The failure of the rows to sum to 1 is due to rounding; all computations were carried out using at least nine-digit accuracy.

The four transition matrices were first tested for lumpability. A Markov chain is lumpable if the set of states $S = (s_1, \ldots, s_n)$ may be aggregated into a set $S' = (s_1', \ldots, s_m')$, m less than n, where each s'_i consists of one or more s_j in the unlumped process. A Markov chain is lumpable if and only if the lumped Markov chain is itself a Markov chain; the transition probabilities of the lumped Markov chain must therefore be dependent only on the state the individual was in at time t and on nothing else. The test for lumpability applied to both the two-state and three-state Markov chains showed that neither the first order nor the second order chains were lumpable.[5] The lack of lumpability makes it logically impossible to consider

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[5] The condition for lumpability is (Kemeny and Snell, p. 197) given here. We first reorder the rows and columns of P so that states which are lumped together lie adjacent to each other. We then construct a matrix V such that $v_{ij}=1$ if s_i is a state lumped in s_j. V has as many rows as P in the unlumped process and as many columns as P in the lumped process, i.e., n x m. We multiply P x V; the lumpability condition is that the entries in the jth column of PV which correspond to states lumped into j must all be equal. In the three-state case, we have the

following

$$\begin{pmatrix} .948 & .028 & .025 \\ .256 & .692 & .051 \\ .353 & .176 & .471 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} .948 & .052 \\ .256 & .744 \\ .353 & .647 \end{pmatrix}$$

Since pv_{22} does not equal pv_{32} we must conclude that the three state first-order chain is not lumpable.

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both the two-state and three-state Markov processes to both be Markov chains; if one assumes that one process is Markov the other is necessarily not a Markov process.

The next test was the order test. Anderson and Goodman have provided a test, as discussed above, that tests the hypothesis that the chain is first-order against the hypothesis that the chain is second order. The order test was applied to both the two-state and three-state models. In neither case was the hypothesis that the model was first-order rejected. See Table III, below.

TABLE III

Order Test

Two-state Model

Chi-square = 1.38, 2 degrees of freedom

Chi-square with 2 degrees of freedom, .05 level = 5.99

Three-state Model

Chi-square = 9.64, 12 degrees of freedom

Chi-square with 12 degrees of freedom, .05 level = 21.0

The second order models were therefore dropped at this point in the analysis.

The next test applied was the test for stationarity of the transition probabilities. It should be noted that this test also tests H6.

The data sets were first aggregated into four time periods in order to increase the N in each time period. The hypothesis tested was that the transition matrix estimated from the entire data set did not differ significantly from the observed transition probabilities in each subset of the whole time period.

The fit of both the two and three-state processes was generally satisfactory. Only one row, row 2 of the three-state Markov chain, differed significantly from the overall p_{ij}'s. See Table IV, below.

TABLE IV

Test for Stationarity of P

Two-State Process

Row	Computed Chi-Square	Degrees of Freedom
1	5.774	3
2	4.433	3
All	10.207	6

Chi-square with 3 degrees of freedom, .05 level = 7.815
Chi-square with 6 degrees of freedom, .05 level = 12.592

TABLE IV (Continued)

Three-State Process

Row	Computed Chi-Square	Degrees of Freedom
1	6.597	6
2	13.126*	6
3	8.031	6
All	27.750	18

Chi-square with 18 degrees of freedom, .05 level = 28.869

* significant

It is interesting to note that the row which does not fit is the row which depends on the proper coding of "military-civilian" regimes. The data quality analysis contained in the Appendix suggests that this coding might be subject to systematic error.

At this point only the first order two state Markov chain model has passed all tests. The first order three state Markov model has passed all but one test; the remaining two models, the second order two state and three state models, have been conclusively rejected. The first order three-state model will be retained in the analysis; the discussion of the models should take into account its failure to completely pass the test for stationarity of the transition matrix.

The two remaining models were then tested to see if the stable vectors differed significantly from the observed proportion of individuals in each state for each subset of the entire time period as well as the entire time period. It should be noted here that this test also tests H5. In every case there was no significant difference between the expected proportions and the observed proportions of individuals in each state, both for each subset of the entire time period and for the entire time period. See Table V, below.

TABLE V

Goodness-of-Fit Test of the Stable Vector

Two-State Model

Time Period	N	Chi-Square	Degrees of Freedom
1	95	.123	1
2	95	.123	1
3	95	1.103	1
4	114	.460	1
All	399	.305	1

$\chi^2_{.05,1} = 3.841$

Three-State Model

Period	N	Chi-Square	Degrees of Freedom
1	95	.340	2
2	95	3.213	2
3	95	1.186	2
4	114	1.677	2
All	399	.342	2

$\chi^2_{.05,2} = 5.991$

Both models, having passed this test, were then tested for the goodness-of-fit between P^2 through P^8 and the observed probabilities of moving from state k to state j after 2 through 8 steps. P^i was computed by raising P to the ith power; the observed probabilities of moving from state k to state j in the same number of steps was computed from the data sets. The observed and expected transition probabilities were compared using the same goodness-of-fit test as in the comparison of the stable vector with the proportion of individuals in each state made above. In all cases the differences were insignificant; four examples, two from each model, are given below in Table VI.

TABLE VI

Goodness-of-Fit Test
of
Transition Matrices P^4 and P^8

Two-State Model

Steps	Chi Square	Degrees of Freedom	
4	1.65	2	$\chi^2_{.05,2} = 5.991$
8	2.15	2	

Three-State Model

Steps	Chi Square	Degrees of Freedom	
4	2.32	6	$\chi^2_{.05,6} = 12.592$
8	2.87	6	

The last test applied to the models was the examination of residuals. The residuals were computed by subtracting the observed probability of moving from state k to state j in i steps from the expected probability. In both the two-state and three-state Markov chains a systematic pattern of residuals was noted. The residual patterns were as follows (Table VII):

TABLE VII

Residual Patterns

	s_1	s_2
s_1	+	-
s_2	-	+

TABLE VII (continued)

Three-State Model

	s_1	s_2	s_3
s_1	+	(-)	-
s_2	-	(+)	+
s_3	-	(+)	(+)

Those signs with () around them occurred a majority of times; those with no () around them occurred every time. The residual pattern strongly suggests the existence of systematic bias; in particular, there is a tendency to underestimate the probability of leaving a state and a corresponding tendency to overestimate the probability of moving to a new state. This pattern suggests the existence of some memory of previous states held by the individual; the order test, however, indicates that perfect memory of the state occupied during the previous year is too strong a condition. An alternative assumption would be the existence of different types of each regime classification, each with slightly differing probabilities of moving to other types of regimes.

Testing Hypotheses and Confirmation

The tests applied to the first-order models have disclosed only one failure to meet a goodness-of-fit test and a general tendency toward systematic bias.. With these conditions held in mind we will now examine the hypotheses generated in the first part of the paper, using the first-order models only.

First, however, we must examine the basis for accepting the first-order models. These models may be disconfirmed on three different grounds: their assumptions, the goodness-of-fit between the observed values and the values predicted by the model, and the acceptability of the data. The third point is discussed in the Appendix. The first two points are discussed here.

The fundamental assumptions of the mathematical model used here are that time is discrete, in units of one year, and that all the individuals in the process are identical with respect to the variable of interest. The first assumption is an assumption often made in political science research, especially in the quantitative comparative field. The assumption amounts to believing that nations can be moved only once a year from one value of a variable to another. At all other times there is no possibility of such a change. This type of assumption is clearly too strong; however, at present, the data is only available on a yearly basis.[6]

The other assumption, the assumption of the comparability of the individuals in the process with respect to the variable of interest, is one accepted by students of the cross-national method but not by some of those in other areas of comparative politics. A full discussion of this assumption, although interesting, would divert us to other topics. It is important, however, to make this assumption explicit.

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[6] I am presently engaged in creating a new data set which takes the regime data now available and combines with that data information from Ruddle and Gillette's chronology of regime changes (Ruddle and Gillette, 1972), thereby creating a data set with smaller time periods.

The level of confirmation of the hypotheses proposed in the first section of this paper, then, rests on the acceptability of the fundamental assumptions of Markov chains. If this is the case we may draw the conclusion that the hypotheses in this study, accepted under the goodness-of-fit criterion, are confirmed, but not strongly so.

Secondly, with respect to the criteria for goodness-of-fit, it should be pointed out that this paper does not assume that the 19 nations are a sample from some universe. In that case, the chi-square tests and confidence intervals derived from those tests do not have their normal meaning. This paper uses those tests as an objective measure of goodness-of-fit, rather than basing the confirmation of hypotheses solely on passing the .05 level of significance. In the final analysis, the acceptability of the model will rest on the assumptions of the model and not on meeting every goodness-of-fit test at the .05 level.

The first set of hypotheses is that of the relative stability of regime types. From our simple model of regime change we hypothesized that the ordering, in terms of stability, would be civilian--military-civilian--military (military <u>least</u> stable). The ordering found in the two- and three-stage models agrees with this ordering. The table below gives the probabilities of remaining in state i given that the process was in state i (p_{ii}) at time t and the associated confidence intervals:

State i	Probability p_{ii}	Confidence Interval
Civilian	.948	.064
Military-civilian	.692	.156
Military	.471	.196

It can be seen that each p_{ii} lies outside the confidence interval of the remaining two p_{ii}.

Furthermore, if we use the method of analysis involving changing the transition matrix to that of an absorbing Markov chain we find that the mean number of steps before absorption into a civilian regime is 3.78 for military-civilian regimes, 3.15 for military regimes. The mean number of steps before absorption in either a military-civilian or military regime, given we reverse the analysis and make non-civilian regimes trapping states, is 19.23. The order of stability remains the same. It is interesting to note that the probability of moving to a military regime first given that the nation-state starts in a civilian regime is .48; the corresponding probability of moving first to a military-civilian regime is .52. The probabilities of moving to either type of non-civilian regime is roughly the same. Furthermore, the mean life of a civilian regime is about 20 years; the mean life of a non-civilian regime is about 3 years.

It can be seen, then, that there is support for the ordering of regime types in order of stability as specified by Hypothesis H1.

We may examine H2, the hypothesis that nation-states first return to civilian regimes before moving to the other type of non-civilian regime by again looking at P for the three-state model. In the following table we have the probabilities of moving to either a civilian regime or to the other type of non-civilian regime, given that the present regime is a civilian regime:

	Regime at time t+1		
Regime at time t	Civilian	Military-Civilian	Military
Military-Civilian	$.256 \pm .095$	--	$.051 \pm .042$
Military	$.353 \pm .169$	$.176 \pm .120$	--

We again find that each p_{ij} is outside the confidence interval or the corresponding p_{ik}. The hypothesis that states return to civilian regimes before moving to the other type of non-civilian regime is therefore confirmed.

We have already tested H5, the hypothesis that the system was in a stable equilibrium. As was shown above the system of 19 Latin American nations has been in a state of stable equilibrium from 1946 to 1966. This finding is not entirely dependent on the choice of a Markov model; it is therefore particularly interesting.

We have also tested H6, the hypothesis that regime types have not changed over time. We have not disconfirmed this hypothesis in the case of the two-state model; the hypothesis has been disconfirmed in the three-state model. There is some evidence that this regime type was systematically biased in the coding process, however. All of these statements must be qualified by the observation that the model showed systematic biases over the 20-year period.

Conclusion

This paper examined a number of hypotheses about the process of regime change and the characteristics of regimes. The major hypotheses were that the system was in a state of stable equilibrium during the period 1946-1966; that the regime types had not changed significantly during that period, that the regimes were ordered (1) civilian (2) military-civilian (3) military in terms of stability; and, finally, that a nation-state in a non-civilian regime state would first return to a civilian regime before moving to the other non-civilian regime type. Support for all these hypotheses was obtained, although not all from the same model. The existence of systematic bias in the predictions and evidence of possible coding errors suggest that the data set quality be thoroughly checked and the analysis then rerun; a more sophisticated model, which makes less unrealistic assumptions about time in particular, might be necessary. The evidence of systematic bias is hopeful, however;

systematic differences from a mathematical model suggest that there are indeed empirical regularities in the data.

APPENDIX I

Data Quality

Three Latin American nations were selected from the Banks file for indpendent analysis. These were Argentina, Cuba,and Mexico. The Banks file lists the regime type for these three nations as follows:

TABLE I

Regime Type, 1946 - 1966

Nation	Time Period	Regime Type
Argentina	1946-1954	Civilian
	1955-1957	Military-Civilian
	1958-1965	Civilian
	1966	Military
Cuba	1946-1966	Civilian
Mexico	1946-1966	Civilian

The possible regime transitions were researched, using Ruddle and Gillette's Latin American Political Statistics (Ruddle and Gillette, 1972); regime transitions for which Banks' coding seemed anomalous were further researched in the New York Times.

Argentina

General Juan Perón was President of Argentina from June 4, 1946 until September 22, 1955. He was forced to resign by the military and replaced by General Eduardo Lonardi. General Lonardi was himself forced out of office by Lieutenant General Pedro Eugenio Aramburu, who led a five-man junta that replaced Lonardi. Aramburu ruled as provisional President from November 13, 1955 to May 1, 1958. A civilian regime was re-established under Arturo Frondizi, who ruled from May 1, 1958 to March 29, 1962. Frondizi was removed from office by the military and replaced by José María Guido, President of the Senate, who ruled as provisional President from March 29, 1962 until October 12, 1963. New elections were held which resulted in the election of Arturo Íllia as President. The military again intervened on June 28, 1966 when Íllia was replaced by retired Lieutenant General Juan Carlos Onganía; the organs of the civilian regime were dissolved.

There is one regime change in the historical record which seems to be, on first glance, miscoded by Banks. This is the regime change in Argentina in 1962. This was researched in the New York Times for 1962. The Frondizi regime was overthrown after nearly a month of crisis. Frondizi allowed the Peronists to compete openly in elections for the first time, resulting in Peronist victories. The military forced Frondizi to annul the election results and place the provinces where Peronists had won power under military rule. This action created a crisis of confidence; the non-Peronist political parties opposed the nullification of the elections, while the military considered Frondizi guilty of allowing Peronism to enter the political arena once again. The crisis continued for ten days, during which Frondizi attempted to organize, without success, a government of national unity while coming under increasing pressure from the military to resign. Finally, on March 29, Frondizi was forcibly removed by the military after he had refused the demands of the three service secretaries and former President Aramburu that he resign. The Presidency was assumed by Guido, who was next in line in the civilian line of succession. The civilian regime continued in office, but the military dictated the terms under which a civilian regime could operate.

These events took place in March, 1962; by December 31, 1962 the situation may have changed. It seems likely, however, that the power relationships which resulted in Frondizi's removal continued to exist. In that case a strong argument could be made that the Argentine regime was of type (2) in 1962, not (1).

Cuba

In Cuba Ramón Grau San Martín was President from October 10, 1944 to October 10, 1948. He was replaced by Carlos Prío Socarrás, who won the 1948 election. Prío Socarrás acted as President from October 10, 1948, to March 10, 1952, when he was ousted by a coup d'etat led by former President Batista. Batista cancelled the scheduled elections, dissolved Congress, and banned political parties. Batista ruled until December 31, 1958, when he fled Cuba after Castro forces captured Santiago and Santa Clara. Castro named Manuel Urrútia Lleo as President and José Miró Cardona as Premier; Urrútia acted as President from January 2, 1959, to July 17, 1959, when he was ousted after Castro resigned the Premiership. Osvaldo Dorticós Torrado became President on July 17, 1959, and Castro resumed the Premiership, a post he had previously held from February 16, 1969, to July.

There is once again a possible contradiction between the historical record and the Banks coding. Banks codes Cuba as (1), or "civilian," from 1946 to 1966; the Batista coup of 1952, however, was entirely based on support from military units. The coup began in the main Cuban Army camp, Camp Columbia; Batista's success was insured after most other army and police units declared for him. Batista himself stated that the coup was based on "captains and lieutenants."[7] If this was in fact true, and Batista's power was based on a coalition of lower-level officers, it is difficult to reconcile this with Banks' coding of the regime as "civilian."

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[7] New York Times, March 11, 1952, p. 12.

Mexico

The Mexican case is rather straightforward. Mexico has been governed since the 1920's by a regime based on the Partido Revolucionario Institucional, the PRI, and its predecessors. There has been perfunctory opposition from the right-wing Partido de Acción Nacional (PAN) and the left-wing Partido Popular Socialista (PPS). The PRI nominee has invariably ascended to the Presidency during the period 1946 to present.

Although a precise categorization of the Mexican government would be difficult, it seems rather clearly to fall within category (1) -- civilian regime.

Summary

In two of the three countries investigated there is some evidence that the Banks data does not reliably code regime type, given the definitions used by Banks. In the Argentine case an argument can be made that the civilian regime did continue in power and was in effective control of the government on December 31, 1962; that argument is much more difficult to sustain in the case of Cuba, however.

The discussion above should indicate to the reader that this paper's conclusions are based on an analysis of a data set of doubtful validity and reliability. The author can only plead that the collection of a new data set or the independent validation of the old data set was a task beyond his resources.

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