Temporal and Spatial Diffusion in the Comparative Analysis of Social Change

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The conceptual and methodological outlines of a new approach to the comparative analysis of social change are expressed in a general time-series regression model which can serve as a framework for developing specific theories of social change for particular variables. The approach seeks to explain the variation over time in a macro-level attribute or action of a social system as a function of a combination of within-system, across-system, and across-time processes: (1) incrementalism or momentum, or the within-system temporal diffusion of the dependent variable; (2) within-system causal development, or the influence of other characteristics of the system itself; (3) spatial diffusion, or the spread of the dependent variable from system to system; and (4) global contextual forces, such as war, depression and shortage of resources. In addition to reconsidering the nature of "the comparative method," the discussion focuses on the process of diffusion and how it fits in with the other processes, especially from a time-series perspective.

Despite the continuing controversy over the nature of comparative social inquiry, the seeds of a new approach to the comparative analysis of social change lie in several relatively recent and seemingly unrelated developments in several disciplines. Careful consideration of those developments suggests the outlines of a new theoretical and methodological framework for analyzing the variation in macro-level social phenomena across time as well as space. Two developments in particular combine to form the foundation for this new framework: first, the increasing attention to the inter-system diffusion of social phenomena and related problems of dependence among societies; and second, the increasing utilization of time-series analysis in the social sciences.

In an increasingly interdependent world, comparative social scientists are beginning to realize that social phenomena occurring within a given society are not isolated and self-contained, but rather are affected by domestic events occurring within other societies. At the same time, analysts of international relations are becoming aware that domestic events occurring within individual societies affect the interactions among those societies as a group, and vice versa. But equally important is the growing understanding that the variation in and covariation among social variables can be analyzed temporally (i.e., across time within a single society) as well as spatially (i.e., across societies at a single point in time). Moreover, temporal patterns of covariation within one society can be compared with corresponding patterns in other societies, and temporal variations within one society may even be causally linked to those within other societies.

While these insights broaden the scope of social scientific explanation, they should be viewed as supplementing rather than supplanting the more traditional perspective of within-system causal development, or the influence on a given dependent variable of other characteristics of the same society. Also not to be overlooked is the ubiquitous process of incrementalism or momentum, in which each change in a given social variable builds on previous changes in that same variable. Finally, all social phenomena occurring both within and between societies are affected by variation over time in such global conditions as war, depression and shortage of resources.

This article develops the conceptual and methodological outlines of an approach which views social change as a function of the four basic sets of processes mentioned above: incrementalism or momentum; within-system development; across-system diffusion; and global forces. These relationships are expressed in a general time-series regression model which can serve as a framework for developing specific theories of social change for particular variables. A different quantitative approach to the study of social change over time (Hamblin, Jacobsen and Miller, 1973), while dealing with
two of the same concepts, namely diffusion and development, treats them as separate processes and never really incorporates them into a single model. Also unlike our approach, it does not employ econometric methods in the analysis of its equations, and consequently does not deal with the process of momentum or incrementalism (e.g., using lagged endogenous variables) or the implications of autocorrelation (which could explain the extremely high $R^2$ coefficients reported by Hamblin, Jacobsen and Miller).

Our discussion will focus on the process of diffusion and how it fits in with the other processes listed previously, especially from a time-series perspective, for this is the key element in the proposed approach. The article therefore briefly reviews and integrates several bodies of literature which seem to have developed fairly independently in several disciplines: Galton's problem; diffusion of innovations, disorder and public policy; and elementary econometrics. But first it will be useful to reconsider the nature of "the comparative method."

**The Comparative Method**

and Units of Analysis

Several unnecessary barriers to the approach outlined here have grown out of the continuing debate over the nature of comparative social inquiry. Many of the debaters seem to have forgotten that all science is inherently comparative (Campbell and Stanley, 1966, p. 6), and precious few have questioned the need to grant "the comparative method" some kind of special epistemological status (see Benjamin, 1977). Ordinarily, non-experimental empirical analysis has involved the examination of the covariation among the attributes of a set of cases at one point in time. Such "cross-sectional" investigation of human attributes is complicated by the fact that human beings exist in groupings, the largest being societies and nation-states, whose "macro-level" attributes affect the "micro-level" attributes of the individuals which comprise them, and vice versa. This situation has two important consequences for the study of social phenomena. First, cross-sectional analyses of the attributes of individuals across social groupings should properly incorporate in the analysis the attributes of the groups to which the individuals belong. Second, the attributes of the groups can themselves be analyzed cross-sectionally, with the group being the unit of analysis, rather than the individual.

It can be argued that "multilevel analysis," which employs both macro-level and micro-level variables in a cross-sectional approach, is the distinguishing feature of "the comparative method" (Przeworski and Teune, 1970). In practice this has meant the use of macro-level variables in studies seeking to explain micro-level phenomena, known as "contextual analysis." That is, many of the participants in the debate over "the comparative method" have apparently assumed that the only variables worth explaining reside at the individual or micro-level of analysis. The debate has therefore focused on various strategies for explaining individual-level behavior manifested within different societies, notably "the most similar systems design" and "the most different systems design" (Przeworski and Teune, 1970). However, Meckstroth (1975) has pointed out that both types of design require the prior specification of the theoretical status of the macro-level variables on which the compared societies are supposed to be similar, or which are to serve as intervening or antecedent variables making a given micro-level relationship different from one society to another. He further argues that "the most similar systems design" tends to overestimate the importance of between-system differences, whereas "the most different systems design" tends to underestimate their importance.

The reasons for this preoccupation with micro-level behavior and the bias against macro-level analysis of societal attributes are not entirely clear. Despite the hazard of reification, complete understanding of human behavior requires analysis of its collective as well as individual manifestations, just as meteorology requires an understanding of the "behavior" of air masses as well as the atoms and molecules which comprise them. Indeed, many of the most important and interesting concerns of social science, such as the actions of governments, require macro-level analysis. Yet one of the principal participants in the debate over "the comparative method" (Lijphart, 1971, 1975) criticizes this type of analysis, branding it "the statistical method of comparison." One wonders why cross-sectional analysis is deemed legitimate when applied to individuals within societies, but not to societies themselves.

The most cogent criticism of macro-level cross-sectional analysis involves the purely practical limitation on the number of cases available for analysis, leaving insufficient degrees of freedom to include enough variables to capture the complexity of social processes (Lijphart, 1971, 1975). The degree of severity of this problem, however, depends upon the unit of analysis and kinds of variables chosen for study. Although there are still only about 150 sover-
eign nations in the world (depending on definitions), many of which do not record much in the way of accurate data, Murdock's *Ethnographic Atlas* (1967) contains fairly complete information on 65 cultural traits characterizing 863 societies. Furthermore, the number of organizations of a given type, such as local governments, within a society or nation-state can be quite large.

In addition to advocating cross-sectional analysis of "sub-system" units, Lijphart (1971, 1975), among others, has recognized the possibility of circumventing the "limited N" problem by adding the time dimension to comparative analysis. The statistically illegitimate method of doing this, called "case-stretching" by Lijphart (1975) and derisively labeled "the multiplicative N-extender" by Sigelman (1977, p. 303), is to include multiple time-point observations (e.g., years) for each case (e.g., nation) in one's data set. Unfortunately, such observations cannot legitimately be treated as separate cases because they are not statistically independent. Another use of the time dimension has been the analysis of successive cross-sections, observing changes in the relationships among variables which vary across a given set of cases at each point in time. But as a number of authors have argued, the dynamic process of social change is best captured by time-series analysis, or analysis of the variation in and covariation among variables which vary across time-point observations of just one case.

In comparative analysis, patterns of temporal variation and covariation in a given set of time-series variables can be compared across cases. Such a strategy, which will be referred to here as "comparative time-series analysis," has been advocated before, most effectively by Moul (1974); but examples of actual empirical analyses employing the strategy are rare (see Peters and Klingman, 1977). It is a variant of a quasi-experimental strategy which Caporaso (1973, pp. 22-26) calls "the control series design" and which most closely approximates the classic experimental design by providing both temporal and spatial dimensions of comparison. Thus it can be argued that the best research strategy for comparative social inquiry is really no different from any other non-experimental strategy based on the general scientific method. Of course, any research strategy entails its own peculiar problems of measurement, and analysis of "aggregate" (macro-level) data is no different, especially concerning the availability of data very far back in history and the comparability of measures across cases and over time within cases (Deane, 1968; Pryor, 1968). Furthermore, time-series analysis (i.e., econometrics) poses some special problems, primarily serial dependence between successive observations, or trend, and between successive residual errors, or autocorrelation (see Ostrom, 1978).

Despite these problems, comparative time-series analysis is the method best suited to address the kind of comparative analysis called for by Teune (1975, pp. 197-98): the derivation and testing of general theoretical statements oriented toward "systems analysis of macro and micro processes . . . cross-system (more than one country), cross-level (individuals and the country or organization) and cross-time (several years)." This statement serves to reinforce the major point of this section, that there is a wide variety of units of analysis at various levels of aggregation whose attributes vary across time as well as space, and the best strategy for analyzing those dimensions of variation does not constitute some special "comparative method." In contrast to the limited number of cases allowed by macro-level cross-sectional analysis, the variation available for study by comparative time-series analysis is limited only by the extent of quantifiable information recorded by history.

Furthermore, comparative time-series analysis can be applied to virtually any unit of analysis for which at least two quantitative variables are available on at least two cases, each with at least approximately ten time-point observations. Such a unit of analysis could range from the individual through various types of groups and organizations and ultimately the society, the nation-state, and even the supranational organization. Moreover, as in individual-level contextual analysis, independent variables characterizing higher-level units may be included in analyses of lower-level ones. Of course, in "aggregate" analysis, variables representing aggregations of lower-level units residing within higher-level ones are routinely mixed in with the "global" or "emergent" properties of the higher-level units themselves.

Finally, the various problems associated with aggregation and disaggregation of data identified by Hannan (1971), among others, do not automatically apply to the approach outlined here. Those problems involve cross-level inference; that is, they primarily concern the extent of agreement between relationships among macro-level variables and relationships among corresponding micro-level variables. Comparative time-series analysis, as envisioned here, instead focuses on relatively identifiable social units, such as nation-states, with inferences involving only one level of analysis, rather than arbitrary aggregations of individu-
als, such as census tracts, with inferences involving two levels of analysis. Although the variables characterizing those units may include aggregated properties of their components and contextual attributes of the larger systems to which they belong, inferences are presumed to be restricted to the level of the chosen unit. Similarly, although the problem of system identification plagues all social research, the special problem of system transformation over time does not automatically apply here, to the extent that the chosen time period covers only the simultaneous, continuous existence of all of the chosen cases. Unlike successive cross-section analysis, in which relationships among variables can change drastically from time point to time point, analysis of variation and covariation across time within each case can capture even major structural changes in continuously existing systems, if the right variables can be identified. The issue of what sorts of structural changes constitute the death of an old system and the birth of a new one remains unresolved and subject to judgment.

The remainder of this article will demonstrate an additional capability of comparative time-series analysis apparently heretofore unrecognized: the ability to incorporate the process of cross-system diffusion into time-series regression models of macro-level social change. This means the ability to model directly the phenomenon of statistical dependence between cases, known in cross-sectional analyses of societal traits as “Galton’s problem.”

“Galton’s Problem” and the Concept of Semi-Diffusion

Apparently the first treatment of social diffusion occurred in anthropology in 1889 with comments by Sir Francis Galton on a research paper by Edward Tylor which interpreted a cross-sectional correlation between two dichotomous (present/absent) societal traits as indicating functional (causal) association. That is, the presence of one trait in a given society was presumed to cause the occurrence of the other trait in that same society, based solely on the observation that most societies which had one trait had the other, and that most societies which did not have one did not have the other. Galton pointed out that the correlation might be spurious because both traits may have been “derived ... from a common source” and were thus “duplicate copies of the same original” (Tylor, 1889, p. 272). Thus, any cross-sectional relationship between two social traits may be an artifact of the diffusion of one or both of the traits, either independently or together, from society to society, rather than a product of causal connection between the two traits.

In subsequent discussions of Galton’s problem, diffusion is seen as transpiring primarily through “pure borrowing” (Ross and Homer, 1976) of traits by one society from another through the usual channels of interaction between societies; through imposition of traits by conquest, colonialism, and economic dependency (Moul, 1974); or through “societal fission” (Strauss and Orans, 1975), primarily migration or separate societal development from a common original. Statistically, Galton’s problem means a violation of the basic assumption of independence among observations. It implies that cross-sectional correlations between pairs of societal traits may be biased and, where sampling of societies is involved, may render standard tests of significance unreliable because the number of independent cases may be much smaller than the total sample size (Naroll, 1976). Galton’s problem has caused great consternation in anthropology and, to a lesser extent, sociology. In comparative political science, on the other hand, it has been largely ignored, either because it is not taken seriously or because it has only recently been noticed at all.

At least ten different solutions to Galton’s problem have been proposed and, as Ross and Homer note (1976, p. 3, n. 9), their number is proliferating rapidly. Keeping an accurate count of them is increasingly difficult as it is not clear which solutions ought to be considered independent inventions and which represent duplication from a common original, due to high levels of interaction within the academic community!

Most of these proposed solutions involve some form of adjustment of cross-section sampling procedures, such as stratification of the sample by region or geographic proximity (Naroll, 1961). Similar in purpose are attempts to remove the effects of diffusion (measured, for example, by the similarity of “linked pairs” of societies) by methods of partial correlation analysis, both first-order (Naroll, 1964, 1970) and second-order (Wirsing, 1975). Such solutions have been shown convincingly to be generally ineffective by Loftin (1972, 1975) and by Strauss and Orans (1975, 1978).

Considerable disagreement continues, however, as to whether the operation of functional (causal) association can be statistically separated from the process of diffusion. Indeed, the arguments have become so varied, arcane, and convoluted that ultimate agreement seems
hopeless. Ironically, the most effective solution is probably also the simplest and most obvious: replication of hypothesized functional relationships within standard sub-regions of the world (Strauss and Orans, 1978). This solution is remarkably similar to Przeworski's and Teune's (1970) "most different systems design" for comparative research, although that design is never acknowledged.

Meanwhile, apparently unknown to these disputants, Pryor (1976) has proposed detecting lack of independence among observations by examining patterns in a "diffusion possibility matrix" based on measures of diffusion potential between all pairs of societies, such as language similarity as well as geographic proximity. A variable based on these patterns can then be included in analyses of functional relationships. Similarly, Ross and Homer (1976) have advocated evaluating functional versus diffusional explanations by incorporating in regression equations measures of diffusion of each of the traits whose functional association is being examined, "such as the score of the geographically closest neighbor sharing the same language" (Ross and Homer, 1976, p. 14). Apparently overlooked by all of the above is Jackman's (1973) treatment of diffusion as a contextual variable influencing the domestic affairs of nations. Jackman suggests measuring diffusion with indicators of international dependence, such as the Trade Composition Index (Galtung, 1971), to reduce specification error in regression models of domestic processes.

Interestingly, the main line of defense for those who refuse to take Galton's problem seriously is a non-statistical argument: that diffusion is unlikely to occur where the diffusing trait is incompatible with the culture of the recipient society (Blaut, 1977, p. 346). Thus, some societies will be "immune" to a trait that is spreading through other societies that find the trait useful (Moul, 1974, p. 152). The diffusion of traits only to societies capable of sustaining them is referred to in the literature on Galton's problem as "semi-diffusion," whereas pure diffusion with no functional basis is referred to as "hyper-diffusion."

Some authors, such as J. de Leeuwe in a comment on Strauss and Orans' first article, go so far as to maintain that "Galton's problem is partly a sham problem and partly practically unimportant . . . for . . . there is the possibility that the diffusion is at least partly an effect of the functional relation between the traits concerned" (Strauss and Orans, 1975, p. 586). Strauss and Orans chide such a notion, claiming that it would make it possible "to avoid Galton's problem by claiming that every case of adoption of a particular pair of diffusing traits is an additional [confirmation] for [one's functional] theory" (1975, p. 584). Nevertheless, in a comprehensive analysis of patterns of cultural diffusion in Murdock's (1967) worldwide ethnographic sample, Smith and Crano (1977, p. 145) find support for the notion of semi-diffusion, asserting that "societies are not passive receivers of traits, but rather that the extent of diffusion is purposive and influenced by trait content." Indeed, the concept of semi-diffusion underlies a key feature of our proposed framework for the analysis of social change: the incorporation of the processes of both within-system development and cross-system diffusion in a single model of social change over time.

**Diffusion, Development and the Time Dimension**

Following its origination in anthropology, the study of the diffusion of social phenomena has sprung up in other disciplines. As with the various solutions to Galton's problem, however, whether this spread was due to diffusion or to independent re-invention is difficult to ascertain, given the scarcity of cross-referencing among studies of the topic in different disciplines. But some disciplines have clearly been slower to adopt (or invent) the idea than have others. The direct focus on the process of diffusion of innovations among individuals and groups as the main engine of social change, rather than on cross-system diffusion as a contaminating variable in within-system causal explanations, has taken firm hold in sociology (Rogers and Shoemaker, 1971; Zaltman, Duncan and Holbek, 1973). This literature reinforces the idea of semi-diffusion, here referred to as "selective adoption," that diffusing innovations will be adopted only if they will be useful for the recipient unit. It also emphasizes the internal characteristics of recipient units in the explanation of the pattern of adoption of any particular innovation.

In political science, the study of the diffusion of political phenomena got started later and, not surprisingly, in several separate sub-areas. The study of the diffusion of political information (Chaffee, 1975) is closest in spirit to the sociological manifestation of the concept, and further emphasizes the effect of the structural characteristics of a communications network on the pattern of spread of a particular piece of information throughout that network. Another political phenomenon seen as prone to diffusion is political instability, notably military coups (Midlarsky, 1970, 1975; Li and
Thompson, 1975) and civil disorder (Midlarsky, 1978). These studies, although methodologically quite different from those previously discussed, also focus on the question of whether disorder diffuses randomly or is influenced by the domestic conditions which characterize disorder-prone political systems.

Because it requires consideration of both within-system and between-system processes, the concept of diffusion parallels the growing attention in the field of international relations to the linkages between domestic and international processes in a shrinking, increasingly interdependent world (Rosenau, 1969, 1976). Similarly, the concept of diffusion echoes the processes of “parallel national action” (Nielsen, 1978) and more formal types of national integration (Haas, 1976), as well as the economic and political “dependency” between less developed and more developed countries (Chilcote, 1978). Nevertheless, within political science interest in the phenomenon of diffusion itself actually took hold, first, perhaps not coincidentally, in the same sub-area as did comparative public policy analysis: American state politics. The seminal work in this new area of inquiry was Walker’s (1969) analysis of the adoption of new policy programs in the states, including the social, economic and political correlates of state innovativeness. Walker’s study was then followed by such refinements as examination of state innovativeness in specific issue areas (Gray, 1973); consideration of the influence of the federal government on policy innovation (Rose, 1973; Menzel and Feller, 1977); and analysis of policy diffusion among local governments (Bingham, 1977). As in the other sectors of the literature on diffusion, attention is turning to such considerations as the characteristics of the diffusing innovation, the internal conditions and characteristics of the adopting unit, and the external pressure to adopt (Eyestone, 1977).

Interestingly, the Walker approach has recently been linked to the concern with Galton’s problem and hence applied to the cross-national context in an overt attempt to assess the relative effects of development and diffusion on the adoption of social security programs (Collier and Messick, 1975). The evidence they seek for the existence of developmental prerequisites for the adoption of social security, and of “hierarchical” diffusion from more developed countries to less developed ones, is mixed. Collier and Messick recognize the likely effect of developmental prerequisites in a pattern of diffusion down the hierarchy of development; yet they fail to directly consider selective adoption or semi-diffusion as an explanation for social security adoption. That is, perhaps countries that have not yet achieved a prerequisite level of development will be “immune” to the innovation (Moul, 1974, p. 152).

Further, although they discuss the diffusion of other phenomena such as technology, labor movements, and liberal ideology, Collier and Messick do not discuss the possibility that the earlier diffusion of these phenomena among susceptible countries subsequently produced social security programs through the internal policy process in those countries. Eyestone (1977, pp. 446-47) expresses the idea more negatively: “Diffusion patterns may record the spread of necessity rather than the emulation of virtue: leaders may lead because they are also the first to suffer the undesirable side effects of urban and industrial growth which create demands for state policy response.”

Although diffusion obviously takes place over time as well as space, most empirical treatments of diffusion have not employed a time-series perspective. Rather, the analyses are still structured cross-sectionally, with such variables as date of first adoption of a policy program or date of first contact with Europeans (Divale, 1976) becoming essentially another static attribute of each case. The problem is that using only cross-sectional analysis, there is no way to determine whether: (1) two statistically correlated traits really are functionally unrelated and were independently re-invented in each society by sheer coincidence; (2) these traits really are functionally unrelated and just happened to diffuse separately through the same set of societies; (3) they were functionally related (i.e., one trait was invented, causing the other to develop) in the society where they originated and then diffused separately or together through the same set of societies; (4) they semi-diffused, with the first trait diffusing through the given set of societies, generating in each the development of the second trait; (5) they developed causally in each society separately, with the first trait being independently re-invented and generating the development of the second trait; or (6) they developed through different processes in different societies. The only hope for disentangling the effects of diffusion and development lies in analysis of these processes as they operate over time as well as space.

Another use of the time dimension has been examination of the across-time pattern of the cumulative number of adopters of a particular innovation, or “knowers” of a given piece of information. The substantive interpretation and mathematical specification of the familiar S-shaped pattern has varied. Chaffee (1975, p.
88), among others, interprets the pattern as a normal ogive, or a cumulative plot of the normal distribution. Thus, it represents a null or random model of the diffusion process characterized by the free flow of information throughout an atomized, unconstrained (i.e., non-structured) communication network in which individuals interact at random. Chaffee notes that the truly interesting patterns of diffusion are instead the non-random ones, in which structural constraints are imposed on the flow of communication. Similarly, the S-shaped pattern of diffusion can be interpreted as a logistic or growth function whose origin, rate and extent are influenced by the process of reinforcement (Hamblin and Miller, 1976). Alternatively, it could be argued that the S-shaped pattern reflects the decreasing marginal utility of innovations, in that they tend to be adopted slowly when they are new and strange, then quickly when they have “caught on,” and slowly again when they become passé. This point will enter into the discussion of models of spatial diffusion appearing later in this article.

In other fields, indicators of external influences have been incorporated into time-series models of basically within-system processes, for example, the influence of Soviet military expenditures on U.S. defense budgeting (Ostrom, 1977), and the influence on state education expenditures of similar spending in neighboring states (Manser, Naylor, and Wertz, 1971). But the first study to take a time-series approach directly to the study of diffusion (Klingman, 1977) examined lags in the across-time relationships among national government expenditures of a given type in Sweden, Denmark and Norway from 1890 to 1965 in an attempt to delineate patterns of regional leadership and followership in the development of policy. That analysis, however, did not attempt a multivariate assessment of the relative importance of indicators of both inter-system diffusion and intra-system development, which is, as this brief review of the literature has suggested, the foremost question in the study of diffusion. The remainder of this article will develop a theoretical and methodological framework which can guide investigations of the role of diffusion and development in specific processes of social change.

**Diffusion and Autocorrelation**

In an interesting application of a time-series concept to the process of diffusion, Loftin (1972, 1975) has drawn a parallel between Galton’s problem in cross-sectional analysis of relationships among societal traits and serial autocorrelation in time-series analysis. He even refers to Galton’s problem as “spatial autocorrelation” and recommends using standard measures of autocorrelation to detect the operation of Galton’s problem in regression analyses of functional relationships among traits of spatially ordered societies (Loftin, 1975, p. 139). He asserts that autocorrelation is “correlation between successive observations” of one variable (Loftin, 1972, p. 430). Such is not the case. Rather, autocorrelation arises from dependence between successive residual errors in estimating a dependent variable on the basis of one or more independent variables (Christ, 1966, p. 228).

Let us examine this difference more closely, first defining the terminology and symbols to be used. The simple regression (ordinary least squares) model for two variables measured across a set of observations (either cases or time-points) is

\[ Y = a + bX + e \]  

(1)

where \( Y \) is an interval-level dependent (endogenous) variable; \( X \) is an interval-level or dichotomous independent (exogenous) variable, or predictor; \( b \) is the slope or regression coefficient (the estimated number of units of change in \( Y \) for each one unit of increase in \( X \)); \( a \) is the constant or \( Y \) intercept (the estimated value of \( Y \) when \( X \) is zero); and \( e \) is the residual error term or disturbance.

For any given observation, \( e \) is the difference between the actual value of \( Y \) and the value of \( Y \) estimated by the regression \((a + bX)\), and represents the effects of all unmeasured variables on the regression. Across all observations, the mean of \( e \) is zero and the magnitude of its standard deviation, called the standard error of estimate, varies inversely with the strength of association between \( X \) and \( Y \). The sampling distribution of \( e \) is assumed to be normal and the variance of this distribution is assumed to be uniform across all values of \( X \) (or expected values of \( Y \), predicted from \( X \) by the regression)—the assumption of homoscedasticity.

In order for these assumptions to hold, the value of \( e \) for any given observation must be random and thus independent of the value of \( e \) (or \( X \)) for any other observation. Thus, the pattern of residuals across all observations should be a random one, even when the observations have been ordered along some theoretically meaningful dimension, such as time or space (i.e., geographic proximity or propinquity—e.g., language similarity, colonial ties, etc.) or simply the value of \( X \) (or the expected value of \( Y \)). When the pattern of
residuals is not random, i.e., when they show a systematic trend across the ordered observations, then the actual values of $Y$ will be consistently above expectation in some segments of the ordering dimension (e.g., the early time period, a certain region of the world, or high values of $X$) and consistently below expectation in others.

Under these circumstances the disturbance term will no longer be random, but instead will reflect the systematic influence of one or more unmeasured variables or non-linearity in the measured variable (i.e., curvilinear relationships between them) or in the regression parameters (i.e., changing values for the slope and constant). The disturbance term is then said to be autocorrelated, and Kmenta (1971, pp. 451–72) shows the difficulty of determining the exact source of the problem. The major effect of autocorrelation is to render inefficient the estimates of the regression parameters and is thus one source of specification error (see Ostrom, 1978, pp. 25–31). Standard tests have been developed to detect the presence of autocorrelation, such as the Durbin-Watson $d$ (Kmenta, 1971, pp. 295–97).

In cross-sectional regression analysis of the relationship between two interval-level characteristics of societies ordered by region, for example, diffusion could indeed be an unmeasured extraneous variable systematically altering that relationship. That is, the dependent variable might be systematically higher than expected in one region because of the spread of that characteristic from one society to the others in that region. It also might have spread less extensively in an isolated region. Diffusion that occurs more extensively within certain groups than others (and less extensively among the groups) is called “segmented diffusion” by Eyestone (1977). Such differential patterns of diffusion might indeed create a non-random disturbance in the regression between the diffusion characteristic and another characteristic having a different or nonexistent pattern of diffusion.

It must be made clear, however, that the problem here is not the trend across regions in the observations of only one of the variables (“correlation between successive observations”), whether that trend is caused by diffusion or anything else (e.g., environmental conditions); rather, it is the systematic patterning of residuals in the relationship between the two variables. If both variables happen to have the same spatial trend (e.g., they diffused in similar patterns), then there will be no systematic patterning of residuals in their relationship. This is true in time-series analysis as well: autocorrelation arises from a non-random disturbance in the relationship between two (or more) variables, rather than from temporal trends within the variables themselves. If the non-random disturbance produces a trend in one variable and not in the other, then it is altering the relationships between them and hence is likely to produce autocorrelation. If, however, the non-random disturbance produces the same trend in both variables, then the relationship between them will not be altered, and no autocorrelation will result.

This latter situation precisely characterizes Galton’s problem, i.e., the diffusion of two functionally unrelated cultural traits among one set of societies and not among the rest, creating a spurious statistical association between the two traits in cross-sectional analyses. But the above discussion should have made it clear that measures of autocorrelation will not detect the similar patterns of spatial trend in the two variables produced by similar patterns of diffusion. Measures of autocorrelation will detect a spatial trend in one of the variables (assuming the cases are sorted along a spatial dimension), whether or not that trend is produced by diffusion; but then, the diffusion of only one variable and not the other is not the central concern in Galton’s problem. We must echo the conclusion of Strauss and Orans (1978, p. 12) that no rote statistical method can ever with certainty distinguish between functional and diffusional explanations of a given cross-sectional distribution of traits. The best cross-sectional evidence of a functional relationship between societal traits is still a similar magnitude of correlation within standard sub-regions of the world. That is, the best control for the effects of pure spatial hyper-diffusion in cross-sectional research is also the simplest: namely, geographic region.

If Loftin (1972, 1975) were correct in claiming that autocorrelation arises from diffusion-induced dependence between temporally or spatially successive observations rather than between residuals, it would be tempting to discuss temporal autocorrelation as arising from temporal diffusion, that is, the lingering influence within each variable of an observation at time $t$ on the observation at time $t + 1$, i.e., trend in the variables. Again, this is of course not the case; rather, serial autocorrelation arises from a non-random disturbance whose effects on one of the variables linger from one time point to the next, thus altering the relationship between the dependent and independent variables (Kmenta, 1971, p. 270). Thus, it is a type of specification error, namely failure to include in the regression model the variable or set of
variables causing the systematic disturbance, rather than a product of diffusion between observations over time. This is not to say that diffusion over time does not take place, for indeed in some situations a trend in time-series observations for a single variable can be viewed as temporal diffusion, with each observation influencing subsequent ones.

Perhaps the most widely known example of this phenomenon is the process of incremental budgeting, one component of which specifies that current budget levels are merely marginal adjustments to the previous year’s levels (Davis, Dempster, and Wildavsky, 1966, p. 533). Regression models of such processes must employ “lagged endogenous variables” (i.e., prior values of the dependent variable) as predictors (Ostrom, 1978, pp. 46–47). The simplest form of such an “autoregressive” model is

\[ Y_t = a + bY_{t-1} + e_t. \]  

(2)

For example, expenditures at time \( t \) might be viewed as an essentially random adjustment to expenditures at time \( t-1 \). Thus the slope might be zero, and if the disturbance is not autocorrelated, then current expenditures will fluctuate randomly around a level trend line. Alternatively, the previous period’s level of expenditure might be viewed as a base on which to build, thereby creating “bureaucratic momentum” (Ostrom, 1978, p. 46). Thus the slope might be positive, and if the disturbance is not autocorrelated, then current expenditures will fluctuate randomly around an upward trend line. If, however, the disturbance is autocorrelated, then current expenditures will be arranged in non-random (e.g., curvilinear) patterns around any trend line, reflecting the systematic influence on expenditures of variables not included in the regression or nonlinearity in the regression parameters.

Unfortunately, the presence of both lagged endogenous variables in the regression equation and autocorrelation in the residuals renders the ordinary least squares estimators of the regression parameters asymptotically biased and inconsistent (Ostrom, 1978, pp. 47–51). That is, the sampling distribution of each estimator will no longer have a mean equal to the true value of the parameter, and the variance of that distribution will no longer decrease toward zero as the sample size grows larger. Specifically, when the autocorrelation is positive, the impact of prior values of the dependent variables on its current values will be overestimated, and the degree of autocorrelation among residuals will be underestimated. The procedures of ordinary least squares and conventional tests for autoregressive relation (notably, the Durbin-Watson \( d \)) must therefore be replaced, preferably by generalized least squares/instrumental variables (Ostrom, 1978, pp. 51–55).

Spatial Models of Diffusion and Development

The use of time-series concepts in the analysis of distributions of spatially ordered variables is by no means new. Most notably, the examination of non-random patterns in the residuals of regression analyses of spatial variables has been used to identify relevant independent variables that should have been included in the analysis (see Berry and Marble, 1968). However, although spatial patterns of the spread of innovations have been modeled using methods other than econometrics, apparently no one has yet suggested using autoregressive models to describe spatial diffusion cross-sectionally. The form of equation would be identical, except that the subscripts of the endogenous and “lagged” endogenous variables would refer to a spatial dimension (e.g., neighboring societies at one point in time) rather than a temporal one (e.g., serially successive observations of one society). Thus, using \( a \) to denote ordinal position in a spatial ordering of societies, the simple autoregressive model would be

\[ Y_s = a + bY_{s-1} + e_s. \]  

(3)

Using the example of public policy, such a model might describe the diffusion of a new policy through an existing interaction network of officials in different governments (Walker, 1969, pp. 897–98), which one might reasonably expect to be reflected in increased levels of expenditure for that purpose among those governments which adopted the policy earlier than among those which adopted it later. The assumption here is that as the policy innovation diffuses through the network, the adopting governments begin increasing expenditures to implement the policy and continue to increase them over time. This creates a spatial trend in expenditure levels across the spatially ordered governments, with successively later adopters having successively lower expenditures. As in the temporal model, the slope could be zero, reflecting no linear spatial diffusion, or it could be positive (or negative, depending on the direction of spatial ordering), indicating the presence of such diffusion. Also as in the temporal model, non-standard techniques would be needed to obtain unbiased and consistent estimates of the parameters.

Autocorrelation of the residuals in this
situation would suggest the influence of domestic-developmental variables or curvilinear patterns of diffusion. In fact, in view of the previously observed S-shaped pattern of diffusion and the theory of the marginal utility of innovations posited earlier, the relationship between neighboring values of a societal characteristic might be expected to be curvilinear. That is, if the variable is interval-level and is one which tends to increase in quantity in a given society over time, then the influence of a given observation on its neighbor should be most pronounced in the middle range of values of the variable rather than in the low or high ranges. This would be expected on the basis of the notion that innovations are adopted least readily either when they are new and strange or when they are passé. Thus the slope of the spatial autoregressive function should be highest in the middle of the spatial dimension and should gradually decrease toward either extreme of that dimension. In other words, the level of the characteristic in one society should influence a neighboring society’s level less when the level is either low or high, but should influence it more when the level is moderate.

Such curvilinearity might be handled by linear transformation, such as the S-shaped “logistic” function (Kmenta, 1971, p. 461):

\[
\log \left( \frac{C}{Y_s} - 1 \right) = a + b Y_{s-1} + e_s \quad OR \quad Y_s = \frac{C}{1 + e^{a + b Y_{s-1} + e_s}},
\]

where \( \log \) is the natural logarithm, \( C \) is an asymptote, and \( e \) (not \( e_s \)) is the natural constant, 2.71828. If, on the other hand, the curvilinearity is in the regression parameters rather than in the variables (i.e., the slope is linear within different ranges of the value of the variable due to uniform diffusion within, say, regions), then those parameters can be estimated by separate linear regressions for each of those ranges (Kmenta, 1971, pp. 451–72). Finally, if the disturbance is still autocorrelated, it may be necessary to attempt to incorporate the variable causing the problem into the regression. Such a variable will most likely be a domestic-development one, such as level of industrialization.

For simplicity’s sake, let us assume there is no curvilinearity in the regression and no diffusion of the developmental variable (designated \( X \)) from society to society. The regression equation would then be

\[
Y_s = a + b_1 Y_{s-1} + b_2 X_s + e_s.
\]

If more than one developmental variable were identified as comprising the non-random component of the disturbance, their inclusion would yield the following general equation:

\[
Y_s = a + b_1 Y_{s-1} + \sum_{j=1}^{K} b_{j+1} X_{j,s} + e_s
\]

where \( Y_{s-1} \) is the value of the dependent variable in the “previous” society in the spatial ordering; \( X_{j,s} \) is a vector of \( K \) domestic-developmental variables operating only within the “current” society; and \( b_{j+1} \) is the vector of \( K \) partial regression coefficients (slopes) associated with those developmental variables. Notice that in this model there is still a “lagged” (in a spatial sense) endogenous variable, but the developmental exogenous variable(s) must not be lagged. Finally, if the disturbance is still autocorrelated, the remaining steps should involve the more complicated procedures of higher-order autoregressive schemes, distributed lags, and generalized least squares (see Ostrom, 1978, pp. 44–55).

Temporal Models of Diffusion and Development

Now let us briefly examine the temporal case in which both diffusional and developmental processes are operating. Here the observations are for a given set of variables characterizing a few single societies, with the variables observed for each society across a given set of time-points, rather than across many societies at a single point in time. In the simplest form of such a model, the dependent or endogenous variable characterizes one society over time, and one of the independent or exogenous variables is that same characteristic, but for a neighboring society. (Again, “neighboring” can refer to propinquity as well as to proximity.) The characteristic is hypothesized to diffuse from the “exogenous” society to the “endogenous” society, and the former’s observations are lagged one period to reflect the time necessary for diffusion to occur. The other exogenous variable in the regression is a domestic-development characteristic of the “endogenous” society and can be either lagged or current with the endogenous variable, according to the theory involved.

The regression equation would thus be

\[
Y_{s,t} = a + b_1 Y_{s-1,t-1} + b_2 X_{s,t-1} + e_{s,t}
\]
where $Y_{s,t}$ is the value of the diffusing variable in the recipient society; $Y_{s-1,t-1}$ is the value of that same diffusing variable in the donor society; and $X_{s,t-1}$ is the developmental variable within the recipient society. Notice that in this model not only is the developmental variable lagged one period, but there is also a lagged endogenous variable which is lagged in both a temporal and spatial sense. This makes the model “autoregressive” in a spatial sense but not in a temporal sense, since the lagged value of the endogenous variable is not coming from within the same society. As before, such a simple model must assume that the developmental variable does not diffuse from society to society.

As with previous models, the relationships may be curvilinear in the variables, as when diffusion transpires more readily when the diffusing variable is at moderate levels than when it is at low or high levels, forming a logistic function. This sort of curvilinearity will appear in temporal regressions if, as might be expected, the diffusing variable is trended, with its values increasing steadily over time. Again, linear transformations might handle the problem. If the relationships are curvilinear in the regression parameters, one solution is to run separate linear regressions within sub-periods. Finally, an autocorrelated disturbance term would again require the prescribed steps of generalized least squares.

Such a basic model can be extended in several ways. First, temporally lagged but spatially “current” endogenous variables may be included to reflect the influence of prior values of the dependent variable on its current value within the recipient society, making the model temporally as well as spatially “autoregressive.” Second, patterns of diffusion among several societies could be examined in sets of equations, each of which uses as exogenous variables the lagged values of the endogenous variables in the other equations. Such an approach would not require the use of simultaneous equation procedures such as two-stage least squares (see Johnston, 1972, pp. 376–84) because no current value of an endogenous variable would ever appear as an exogenous variable—only lagged values.

Combining all of this yields what might be considered a framework in which to develop specific low-level theories of social change that include cross-system diffusion as well as within-system developmental and incremental processes. Empirical analyses employing such a framework would conceptually require the use of a three-dimensional raw data matrix (variable by society by year). To be amenable to standard computer programs, however, this “data cube” (or, more precisely, “data parallelopiped,” since all three sides would not necessarily be equal) would have to be collapsed into a more conventional two-dimensional matrix, as required by the particular program.

The general form of the regression model for such a framework, using slightly different notation, would be

$$Y_{i,t} = a_{i,t} + \sum_{j=1}^{N} b_{i,j} Y_{j,t-p} + \sum_{k=1}^{K} b_{i,k+N} X_{k,t-q} + e_{i,t} \quad (8)$$

where $Y$ is a diffusing endogenous variable (e.g., level of expenditure for a diffusing innovative policy) varying over both time (dimension $t$, from 1 to $T$ observations) and space, denoted by two dimensions, each ranging from 1 to $N$ societies: dimension $i$ for the recipient society and dimension $j$ for all societies “donating” the variable to the recipient society. That is, $T$ would define the length of the time period and $N$ the set of interacting societies involved in a particular theory. It is important to note here that by allowing $i$ to equal $j$, one of the “donor” societies is the recipient society itself in the previous period—that is, the lagged endogenous variable, $Y_{i,t-1}$, the presence of which again would require the use of such non-standard procedures as instrumental variables in order to make unbiased and consistent estimates of the parameters. Note also that the remaining “lagged endogenous” variables, $Y_{i,t-p}$, are not really endogenous because they emanate from outside the $Y_i$ vector.

Again, no simultaneity is involved in this equation because all terms on the right-hand side are time-lagged. $p$ here is the number of periods of lag involved in the diffusion process, and could be conceived in more complicated theories as varying over time or pairs of societies. The right-hand side of the equation also contains an array of $K$ domestic-development exogenous variables, denoted $X$, each varying only over time within the recipient society. $q$ here is the number of periods of lag for the effects of these exogenous variables on the endogenous variable. It may or may not equal $p$, and in more complicated theories it may vary from variable to variable or over time. The terms $a$, $b$, and $e$ in the equation retain their usual regression meanings.

Finally, a fourth element in the process of social change can be viewed as a set of broad-gauge contextual variables operating only
over time and affecting all variables included in the model thus far: namely, global conditions which affect all societies, such as war, depression, and shortage of resources. Adding this dimension to Equation (8) yields

\[ Y_{i,t} = a_{i,t} + \sum_{j=1}^{N} b_{i,j}Y_{i,t-p} + \sum_{k=1}^{K} b_{i,k+N}X_{k,t-q} + \sum_{m=1}^{M} b_{i,m+N+K}W_{m,t-r} + e_{i,t} \]  

(9)

where \( W_{m,t-r} \) is a set of \( M \) global contextual variables varying only over time and lagged by \( r \) periods. Again depending on the theory involved, \( r \) may or may not equal \( p \) and/or \( q \), and perhaps could vary from variable to variable or over time.

Including these global contextual variables in the model, of course, entails the risk of multicollinearity between these variables and the other exogenous variables in the equation, notably the within-system developmental variables. The extent of multicollinearity, however, would be an empirical problem contingent upon the specific social change process involved. A complete path model would incorporate links between such global indicators and the other exogenous variables as well as the endogenous variable. Such a model might be amenable to the recently developed methodology of maximum-likelihood estimation of structural equation models (see Jöreskog and Sörbom, 1977), but a thorough examination of this possibility is beyond the scope of this article.

It should be noted that not all terms implied by this general model would have to be included in a given specific model; rather, many terms could be excluded for either theoretical or statistical reasons. In particular, including more than one domestic-developmental variable \((X)\) would increase the danger of multicollinearity. The appendix depicts the simplest example of a model using government spending on social welfare programs and rates of industrialization in three countries. Ignoring for now the effects of global contextual variables, the influences on spending include not only a form of incrementalism (Davis, Dempster and Wildavsky, 1966, p. 533) and such within-system influences as industrialization (Herber, 1967, Ch. 17), but also cross-system emulation (Nelson, Naylor and Wertz, 1971).

For some sets of countries or some periods, however, some of the linkages depicted in the appendix may be deemed irrelevant on the basis of a priori theory or external information, or some may prove to be statistically insubstantial or to cause multicollinearity. Other than superfluous indicators of domestic development \((X's)\), the most likely candidates for elimination from such a model might be several of the cross-system linkages, because governments probably emulate only certain other governments rather than all of them. Again, the general regression model is designed to be a framework in which specific theories can be developed rather than an all-encompassing theory itself.

Summary and Conclusion

This article has developed a new approach to the analysis of social change by bringing a comparative time-series perspective to the concept of diffusion and incorporating it into time-series regression models of incremental development. Basically the approach, summarized in Equation (9), seeks to explain the variation over time in a macro-level attribute or action of a social system as a function of a combination of within-system, across-system, and across-time processes: (1) incrementalism, or within-system temporal diffusion of the dependent variable, i.e., the dependence of the current observation on previous ones; (2) within-system development, or the influence of other characteristics of the system itself, with appropriate time lags; (3) across-system diffusion, or the spatial diffusion of the dependent variable from system to system, again with appropriate time lags; and (4) global contextual influences, again with appropriate time lags. This approach, while seemingly complex and methodologically difficult, actually provides a realistic and parsimonious perspective on macro-level social change.

The theoretical and methodological framework outlined here has been derived by merging the literature on the concept of diffusion in several disciplines with the methodology of comparative time-series analysis and, less overtly, with research on within-system development. One of the common themes in the disparate literature on diffusion is the need to consider conditions within systems in analyzing the spread of traits across systems, because systems will vary in their receptivity to external "stimuli." At the same time, analysts of development have begun to realize the possibility that system attributes and actions arise from outside the system through diffusion rather than from inside the system through functional causation.

This article has suggested that both schools of thought can advance even further by adopt-
ing a time-series perspective on social change, embracing such concepts as lag, momentum, and incrementalism, and by recognizing the influence of changing global conditions over time on all social systems. Such an approach will facilitate a return to the fundamental purpose of comparative analysis: to explain sources of variation over time and space in the social phenomena which interest us, regardless of whether those sources are internal or external to the social units we study. Such explanation will require not only the broadened conceptual perspective suggested here, but also the broadened methodological perspective provided by comparative time-series analysis of quantitative historical data on as many social units as possible, for as long a span of time as possible.

References


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\[
Y_{1,t} = a_{1,t} + b_{1,1}Y_{1,t-1} + b_{1,2}Y_{2,t-1} + b_{1,3}Y_{3,t-1} + b_{1,4}X_{1,t-1} + e_{1,t};
Y_{2,t} = a_{2,t} + b_{2,1}Y_{2,t-1} + b_{2,2}Y_{1,t-1} + b_{2,3}Y_{3,t-1} + b_{2,4}X_{1,t-1} + e_{2,t};
Y_{3,t} = a_{3,t} + b_{3,1}Y_{3,t-1} + b_{3,2}Y_{2,t-1} + b_{3,3}Y_{1,t-1} + b_{3,4}X_{3,t-1} + e_{3,t};
\]

Source: Compiled by the author.

Key:  
Y_1 = expenditures in country 1  
Y_2 = expenditures in country 2  
Y_3 = expenditures in country 3  
X_1 = industrialization in country 1  
X_2 = industrialization in country 2  
X_3 = industrialization in country 3