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## ADAPTIVE PROBLEMS OF SOCIETIES: DETERMINING CRITICAL PERIODS IN THE HISTORIES OF BRITAIN, FRANCE, GERMANY AND ITALY

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## Determining Critical Periods in the Histories of Britain, France, Germany and Italy

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ABSTRACT

The use of time series data in comparative history and in comparative societal analysis offers rich possibilities, but simultaneously theoretical and methodological problems. In this paper we explore how one can create continuities and discontinuities in time series data, and especially in critical dimensions that relate to a wide range of disciplines and paradigms. Although our illustrations are all from a particular study, the solutions appear to be generalizable. The conceptualization of periods can occur on two levels, one much appreciated and one largely ignored. They form the basis of the organization of this paper. The second level offers much richer insights, but is also much more difficult to determine.

# Adaptive Problems of Societies: Determining Critical Periods in the Histories of Britain, France , Germany and Italy

The use of time series data in comparative history and in comparative societal analysis offers rich possibilities, but simultaneously theoretical and methodological problems. While the statistical problems of serial correlation are well known, there are other issues. What is the best way of standardizing time series data both comparatively and longitudinally? How does one handle the problem of missing data? How many time points should be included? How can time series be employed to conceptualize one or more societies at critical junctions? And, perhaps more fundamentally: How do the solutions to any of these problems affect the analysis?

Beyond these methodological questions lie a set of theoretical problems. How can time series data be employed to afford new insights about a nation or a set of societies? Too often methodological problems are solved without an eye to such substantive issues; just as frequently, theoretical choices are made without a consideration of the methodological implications involved. One task is to merge theory and method as much as possible in the same discussion. At the minimum we are interested in how substantive and methodological issues intertwine.

The theoretical problem that we pose is that old, hoary historical concern of how best to periodize eras. Frequently major events such as wars and depressions, revolutions and political regimes have been employed. Whether the revolution of 1848, the Dreyfus Affair, World War I, the Weimar Republic, the general strike of 1924, the sit-down strikes of 1936, the Fifth Republic, or the night of the Long Knives, etc., historians have frequently taken events or political periods as the bench marks. There is reason to question this method. One can make the case that there was continual centralization of power during the Weimar Republic and more concentration of power than in the Empire, that almost every major achievement associated with the Fifth Republic was the continuation of trends started before De Gaulle came to power. Indeed, the striking characteristic of the Fifth Republic is the stabilization and the stopping of further expansion in many areas during the late 1960s with the stabilization of the central government budget (André and Delorme 1972).

Long time studies of economic growth in Europe (Bairoch 1977) indicate that the great depression was an interlude in an otherwise <u>accelerating</u> economic expansion, and this is especially true for Scandinavia, Germany, France, and Italy. Here the major exception is Britain, which contrary to current perceptions has had economic stagnation for almost a century. What is clear in these many examples is that when one quantifies a variable, creates a time series, and then examines what the French historians would call the longue durée, traditional conceptions of discontinuities disappear in many instances. Instead of thinking of the event, one wants to ask: What is the phenomenon and how does it vary across time? Tilly (1976) has demonstrated for France how conflict has been and is a persistent characteristic with considerable undulation but permanence nevertheless.

This may mean that the current emphasis on the analysis of social legislation may be misguided if the social legislation is perceived as a discontinuity. For example, the French made primary education free in 1881, but the proportion of students being given free education had been steadily climbing throughout the 19th century and hit close to 60% just before the legislation was passed. The free medical assistance program passed in France in 1894 actually started in 1852 when the central government offered to aid communes that had large welfare budgets especially because of this problem. It was a match granting program but it would be a mistake not to see its earlier origins. Much of social security really emerges out of the mutual aid societies that started in the 19th century. Governments take them over when they reach a certain size or when they decide that their welfare costs were getting too high. This appears to be the consequence if not the motivation of the British and French legislation in this area. This is not to say that there are no Bismarks or remarkable pieces of legislation, but to say that one wants to be very careful and not to make the mistake in believing that there are no precursors. A shift from private to public administration, which is essentially what has been the origin of most social security programs, may not be worth much attention. Likewise, the point at which a category of people being aided becomes large enough that it is made a separate program may be the far better way of conceptualizing the phenomenon. Time series--when properly conceptualized--allows one to perceive the essential continuities where none previously existed.

Social scientists are more likely to have difficulties of an opposite kind. They are more likely to perceive continuity where discontinuity exists. For example, industrialization and modernization are constant processes almost without beginning and without end. Once one does create a time series, and assuming the concepts are not bound by historical time and space or limited in range as is percentage literate or miles of railroad track or number of television sets, then it is not immediately apparent that there are critical thresholds where one can say a new age has dawned. The problem, relative to historical space and time of concepts, is their consequences for use of continual time series data and the implications of this for providing an unique and unequivocal definition to what history is, historical sociology and sociology (or any social science for that matter, unfortunately cannot be spelled out given the limitations of this paper; but see Hage [1972, Chapter 1] for a preliminary statement). Certainly the controversy over Rostow's theory of take-off (Rostow 1960) indicates that the establishment of thresholds is not a simple matter. At the same time it strikes all social scientists, at least since Marx, that there are discontinuities, qualitative changes along quantitative dimensions. The current interest in post-industrial society (Bell 1973) indicates this. But the delineation of meaningful qualities, poses conceptual and methodological problems.

Thus, social scientists and historians are in agreement about the necessity for periodization, albeit the former might stress continuity and the latter discontinuity. But what are the best ways to conceptualize societal eras? Admittedly, what is a meaningful period will vary enormously depending upon the intellectual problem that one poses. However, we believe that time series data offers several ways of tackling this problem of periodization. Our suggested solutions appear to be easily adaptable to any problem that interests the researcher, provided that at least some continuous series is available or can be assembled from original sources.

For the purposes of illustrating how periodization can be studied both descriptively and analytically, we have decided to use examples from our current work on the problem of resource allocation, especially by governments and at all levels. (Although we would like to include the private sector, we have found it difficult to estimate private expenditures for the periods prior to World War II.) For our discussion, we will limit our focus to the question of social expenditures; i.e., governmental allocations to health, education and welfare.

Our approach conceptualizes the resource allocation question as how demands for social services arising out of changes in social structure are met with supplies of expenditure, to what extent are they met, and how rapidly. Once the problem is focused in this way, a whole series of subsidiary issues emerges:

1. How does one measure social need or demand for expenditures?
2. How does one measure the meeting of these needs or supply?
3. When are governments more or less responsive to demands?
4. How do these needs and responsiveness to them change over time?

And this leads to our first observation, namely that periodization is most likely to be successful when it taps fundamental concerns that connect a number of disciplines.

The essential conceptual issue in periodization is to find meaningful continuities and discontinuities. If this is so, then the test of any proposal to periodize is best done when there would appear to be many opportunities to make a mistake. In a particularly critical geopolitical area and era, namely Britain, France, Germany, and Italy during the past century, 1870-1965, this is the case. This is the period when most social legislation came into existence. These countries have been ravaged by wars and revolutions, booms and busts, short and long political periods. If one wanted to choose a geographical area and time period where there has been an enormous number of shocks, upheavals, and seeming discontinuities, these four countries during the past century provide the perfect test of the efficacy of our procedures.

They also provide a test of the efficiency of using dramatic events as meaningful bench marks. Did World War II really make a difference? Everyone experienced it as a cataclysmic event, but that does not mean it changed peoples needs or governmental responsiveness to them. And if they did change, to merely cite the war begs the question of in what way.

The objective then of this paper is to explore how one can create continuities and discontinuities in time series data, and especially in critical dimensions that relate to a wide range of disciplines and paradigms. Although our illustrations are all from a particular study, the solutions appear to be generalizable. The conceptualization of periods can occur on two levels, one much appreciated and one largely ignored. They form the basis of the organization of this paper. The second level offers much richer insights, but is also much more difficult to determine. But before one can describe and analyze periods, there are a number of methodological problems that must be addressed.

## 1. METHODOLOGICAL AND THEORETICAL PROBLEMS OF MEASUREMENT IN HISTORICAL TIME SERIES DATA

Before we begin to look at time series data, we must decide how the data should be standardized, how many time points are necessary and how missing time points can be estimated. These choices are closely tied to the conceptual approach chosen. The concept of demand or need of education provides an interesting example of how complex these conceptual and methodological issues are.

Issues in Standardization

As a general rule we have been interested in standardizing almost all of our analytical variables as proportions of one kind or another. Proportions have a number of attractive features. A percent is readily interpreted by readers. Unstandardized beta coefficients in regression equations using percentages are easily understood. One can create equations more easily and form meaningful new variables much more readily. Proportions as direct standardizations control for a number of changes that we would not want included. Germany had a rapidly expanding population during the period 1871-1939 whereas France did not. Likewise there are periods of rapid and slow economic growth. One would not want these to be confounded in any analysis of public expenditures. Ideas like Wagner's Law (Peacock and Wiseman 1961) that social expenditures increase as a function of economic growth appear to us misleading and ignore the current stabilization and the previous period prior to the 1880s (Musgrave 1969, Wilensky 1975). What is more interesting is to explain when the proportion of GNP allocated to education, housing, public health, or the like increases or decreases and why. This controls for inflation and economic growth and avoids the many problems involved in computing exchange rates. For most of our work we have standardized economic variables on GNP or NNP and demographic variables on relevant target populations such as ages 6-19 for school or 15-44 for births. This is true even when the objective is frankly noncomparative or a single case study. It is our belief that one falls too quickly into the pitfall of accepting the notion that greater wealth means greater expenditures. Just as one desires to control for the size of the target population one should also control for the size of GNP.

Which base one chooses depends upon the problem at hand. If one is more interested in analyzing the relative priorities of particular governments, then the percentage of the government allocation spent on a specific category such as education or health and welfare can be a much more appropriate measure than a proportion of GNP. Here we are only arguing that a proportion is a very useful metric because of its flexibility. Which denominator that one employs is a theoretical problem and much more complicated than the existing literature suggests. A central key is to search for variables that are general (Hage 1972) and independent of space and time, and to choose denominators that control for spurious conclusions. For example, per capita expenditures do not seem a very desirable way of proceeding for our problem although they might be advocated for statistical reasons.

However, if one uses proportions, please observe that one has bought an epistemology that is social scientific and not historical in nature. Although the content of the variable can still be historical, the perceptual thrust of the proportion of GNP spent on social expenditures or the proportion of adults ages 20-24 in higher education or the percentage of the labor force unemployed or the proportion of women in the air pilots union is to be more concerned with general variables that cut across historical time and cultural space. This need not be so but the bias is evident.

One may choose to standardize on some variable that is specific to a particular country. For example, what proportion of the students ages 20-24 are in the grandes ecoles tells us a great deal about the size of elites in France but is a phenomenon quite particular to that country. Or the proportion of the total vote for the labor party and how this has changed over time becomes of special interest in Britain and in a few other countries. But if one wants to make comparative statements it is not the way to standardize. Instead one wants to take proportion of left vote or proportion of left-center vote depending upon how one conceptualizes the labor party in Britain. Likewise, for comparative statements, grandes ecoles in France might be categorized as elite schools of higher education. Then historical form and substance will vary from society to society but there are structural equivalents (Przworski and Teune 1970, Warwick and Osherson 1973). This then leads to our second theoretical point, namely that the variables should not only be standardized but also be independent of time and space.

To illustrate how proportions can be used and also how many conceptual problems there are in delineating meaningful periods, let us take as an example the demand for public expenditures for education. One way to conceptualize demand is to start with the proportion in school ages 6-19.[1] Clearly this is a proportion that can vary between 1% and even sometimes in the distant future be more than 100% if the entire age cohort finishes university. One wants to translate these proportions as a target population into a demand for government expenditures. At this point the problem becomes interesting and we return again to the importance of conceptualization.

It is commonplace in the literature to find the number of people age 65 and over correlated with the social security expenditure or the number of students ages 20-24 in higher education with educational expenditures (Pryor 1968, Musgrave 1969, Wilensky 1976). But if one wants to conceptualize demand, then the central concern is what is the demand for expenditure, and public expenditure at that. As the target populations change in particular categories, then the costs shift enormously. Unemployment compensation is a relatively cheap program, but old age pensions becomes expensive if longevity shifts from an average of 45 to 65 years for the male population as it has during the past 100 years. Taking care of orphans was a relatively big but inexpensive program in the 19th century, taking care of mental retardates is now a relatively small but potentially quite costly program.

The cost of primary, secondary, and higher education differs because of varying teacher-student ratios, size of plant and the technological intensity. Clearly educating 100 college students is not the same as educating 100 primary students. The cost of secondary and especially technical and vocational school students is much higher than the cost of educating primary students. Recent studies of the per capita cost of various forms of education have made this all too apparent.

An arithmetic increase in proportion of the cohort being educated represents a geometric increase in demand for government expenditures. The increase in percentage of the 6-19 cohort enrolled does not represent solely the addition of the more expensive higher grades of education, although this is a large part of the increased need for expenditures. At the same time there is growth in secondary education, there is the creation of special technical or vocational schools. Although 90% of the primary age children can be taught how to read, write and count cheaply, the remaining 10% require expensive special education. The expansion of education requires more than laws making attendance compulsory but also developing the pedagogy and the different kinds of schools that makes it possible and inevitably this is disproportionately expensive. Studies of technical education at the secondary level in France indicate that it is almost as expensive as university education.

One difficulty is that the process of modernization, i.e., expanding knowledge and technology, makes primary education more expensive as well as higher education in addition to the factors we have already noted. The conceptual problem is easy to state: How much is the growth in demand for public expenditures a demand for traditional programs and how much is it demand for qualitatively more expensive forms of education within each level?

This simple statement leaves a host of problems to be solved. If one takes the differences in per capita cost of primary, secondary, and higher education at one time point as a way of estimating the costs per student, then this is unlikely to be relevant for other time periods. The exponential for one country can be quite different than it is for another, and ignores the issue of productivity or more efficient solutions. For example, traditionally Britain has made higher education quite labor intensive and therefore expensive whereas France has not except for the grandes ecoles. Technical education at the secondary level has been favored in France but not in Britain. This implies using some cross-section of countries, but may not speak to the problem of how the modernization process may be affecting the costs per student itself within each nation. As yet, a satisfactory theory of modernization has still to be written, and especially one relative to areas other than the economy. But at the minimum it appears to us that the growth in knowledge leads to the recognition of new solutions to old problems and new problems. New demands are created and should be supplied, which affects the desire for quality and its attendant costs. How one measures this, and especially relative to the specific areas of education, health and welfare, government including defense, art, etc., is yet unresolved.

Our own hunch is that if a satisfactory measure of the growth of knowledge or modernization could be found, then this could be used to predict the costs per student that would translate the growth in the proportion of a target population being served into a demand for public expenditures. But this remains to be done and is a current way in which we are trying to create new variables for quantitative history. The solution of an adequate measure of modernization seems essential to any analysis of the longue duree and it is clearly not the same as industrialization, as the comparative histories of Britain, Germany, Italy and France indicate.

Perhaps more critical is the complaint that we have estimated demand by the number of students in school rather than the number of students who would like to be in school, a standard problem in economics. We are aware of this deficiency and are exploring several idealized models of growth curves in demand that would then be employed to estimate "true delays." For example, a logistic curve and a steady incremental model that adds to the median years completed on one year every 12. Again, how one measures and standardizes the data makes a great deal of difference. In Britain ignoring the science classes from the 1850s through the 1890s is to miss the growth in secondary education and especially for the working class, which represents the vast bulk of the target population. This is a process that is paralleled in the growth of the ecole primaire superieur and cours complementaire in France at about the same time.

Although we advocate proportions with general variables, we also believe that they must be manipulated in various ways to make theoretical sense. To just use a proportion across time, again depending on the problem at hand, is to miss the larger theoretical issues and sink into quantification for the sake of quantification, a tendency that we observe in the current interest in historical time series data. Here mathematical equation forms can be helpful in conceptualizing the problem.

The Number of Time Points and the Problem of Estimation

So far we have discussed the problem of standarization with examples. We have not considered the problem of how many time points to use and how to handle missing data.

The basic starting point is that one wants the same number of time points on all variables and when estimating one does not want to artificially create association between variables. We believe that all can agree on these desideratum. But these guidelines pose other difficulties. The same number of time points begs the question of how many. In general, we find yearly measures to be quite satisfactory. Unfortunately there has been a tendency to emphasize decade measures that have the consequence of eliminating swings and inflating correlations. It is true that some variables change slowly, for example urbanization, political development or participation, or an index of income equality, but many other variables change their slope much more frequently. However, not to cover a long enough time period, such as one century or more, is to miss changes in the slopes or even perhaps the impact of particular variables. For example, historical demographers in France (I.N.E.D. 1976, 1975) have now constituted a fairly reliable set of population statistics for each year from 1749. What is striking is that the decline in birth rates starts long before the impact of industrialization (20th century, depending on definition) or the decline in infant mortality (mid-19th century) in France and much earlier than in corresponding Western European countries.

A good illustration of how meaningful swings can be for understanding the larger issues that we posed at the beginning of the paper is an analysis of the relationship between unemployment and local government expenditures on health, welfare, and housing in Britain between the two world wars. Britain had a distinctively different pattern of unemployment, large and fluctuating until 1939. Each fluctuation was followed rapidly by an increase or decrease in these expenditures. Clearly local governments were trying to cope with the problem by shifting their resources to this need. Decade measures would not only obscure this responsiveness but miss a critical insight about the role of local government in meeting needs, an issue that has been raised in the literature. Admittedly for certain problems more frequent measures than annual ones are needed. Riots, strikes and the like have much shorter time spans and require monthly or even daily measures. Nor do all problems require a longue duree or a century or more. All that we would suggest, however, is that the delineation of historical periods with time series data does work best when at least a century of yearly measures is employed. Then periods become apparent and one is more likely to think about the relative causes. We have already noted that the imagery of the importance of particular legislations is changed when one has time series data about the relative growth of the phenomenon such as free education, social insurance and the like. Similarly, economists have observed that the depression was really a temporary lull in the expansion of GNP and that past retardation tends to be recovered. These insights only come with time series spanning a sufficiently long enough period to cover major booms and busts, cycles, or interruptions.

But what does one do when there is missing data or worse yet when the phenomenon itself may be present only once in a while? A classic example is party vote. Elections only occur once every few years. During certain periods they may be totally suspended. How does one create yearly measures and if one does, what meaning does it have? We have used a special cubic function to interpolate missing data that tends to emphasize fluctuations rather than trends in the data. Built on the previous three data points, it will project forward or backward magnifying any deviation from a constant rate of change. The formula is a cubic polynomial spline which, in effect, smooths the data at the same time that it estimates the missing time points. It has the flexibility of allowing for a greater or lesser tightness of fit to the actual data points that exist. Theoretically, relative to the problem of political party vote, we have created a continuous series that represents what might be called the mood of the country. Public opinion polls, panel studies and common parlance indicate that left, center and right sentiment is constantly shifting and may peak before or after an election, so that estimating yearly measures on the basis of election votes is not as far-fetched as it may sound.

With other variables, interpolations that emphasize swings more than trends have many statistical advantages. It means that one is not creating associations between variables which is what is more likely to occur with linear interpolations. Since this interpolation program uses all available data in estimating the particular missing years there is also a greater emphasis on the peculiarities of the individual time series. For example, urbanization, however defined, is quite linear whereas party vote is not. Thus, we find this particular program to be quite useful for solving the missing data problem. We might point out as well that having even qualitative estimates, however soft, are better than nothing at all when attempting to estimate missing periods.

This is especially important because the more frequently one can at least estimate time points, the better this or any interpolation program will work. We have found that when ten consecutive time points are being estimated, the program is less successful. However, ten time points scattered can be estimated with little distortion. But if one creates a series of estimations connected by interpolations is not one constructing a house of cards? The answer is--not really. Different estimations and interpolations can be checked for the general plausibility both from the standpoint of the different periodization they create as well as their pattern of association with other variables.

Within each of our countries, particular analytical variables have proved a problem. For example, in Italy union membership in the post World War II period has been a secret. We have used some "soft" estimates based on attendance of delegates at conferences and interpolations between these estimates. Likewise, English public education statistics in the 19th century are very misleading without some attempt to estimate the private sector. This leads us to another general conclusion--estimation or interpolation, however crude, is better than nothing at all. To accept public documents as is or the absence of data as a *fait accompli* is to seriously distort any effective description and analysis. Indeed, one would hope that all these many centuries of historical scholarship would provide a very solid foundation upon which to make estimates and to check interpolations. And yet, one suspects that it is the historian who is best equipped to say that such and such a percentage of the population needed welfare that will be the most reluctant to assign a number. If we restrict quantitative history and social science to numbers that are readily available, then almost all the really interesting problems are unanalyzable. What we feel is called for is the development of good time series data, yearly measures based on the correction of public figures as we have done with French education statistics or the compilation of public documents that have not been used before as we have done with Italian local government expenditures or the use of qualitative sources to help, mixed with quantitative ones as with British education statistics.

If any real progress is going to be made in quantitative history, it will be by putting together original series, preferably of a comparative nature, based in part on qualitative sources. This is exactly the direction in which econometricians have moved and understandably so. The creation of estimated GNP or NNP time series have made an enormous difference in allowing for the analysis of a society across time. We have thought of creating a comparable social achievement index that would emphasize growth in a number of social outputs rather than the emphasis on economic production *per se*. We need to identify other critical continua like these where we can concentrate our energies. Likewise, some very sophisticated population series are being gradually put together, including fertility rates. The same must be done with political and sociological variables. But note the breakthroughs here are more conceptual than questions of what are available. Once the theoretical concept can be defined, and assuming it has some strategic relevance for other problems and issues, then probably the data can be found or at least estimated.

In summary, our guidelines are as follows:

1. Employ proportions whenever possible.
2. Generalize the variables as much as possible, even if the interest is non-comparative.
3. Obtain at least yearly measures for a longue duree of a century or more.
4. Use non-linear estimation procedures.

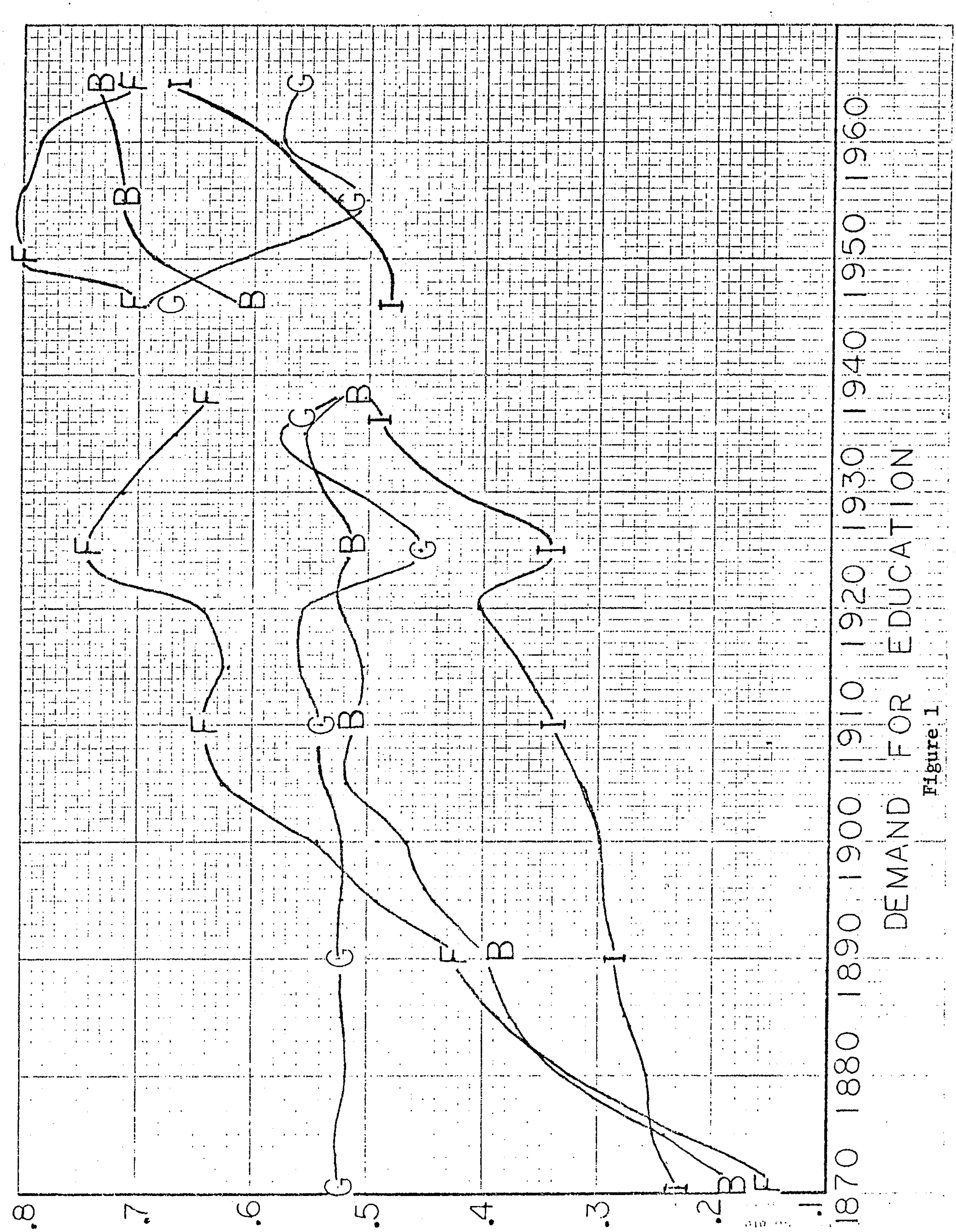
Throughout our discussion we have placed a heavy emphasis on the importance of the way in which one thinks about the variables.

## 2. PERIODS: THEIR DESCRIPTION

### Changes in the Rate of Change as Periods

Four demand curves are plotted in Figure 1. The data plotted, however, do not necessarily reflect all the corrections we have discussed. We did not have time to finish the purification and estimation of the British data nor did we have time to include a much more accurate series of the French student data. But nevertheless, these graphs can illustrate some of the central issues in our approach to periodization.

The trace lines show some distinct patterns. Germany (The Bundesrepublik in the post-World War II period) is remarkably stable with only minor fluctuations associated with the economic crisis of the early 1920s and the post-World War II bulge. Essentially our end point (1965) is little different from the 1871 starting point. France begins at a considerably lower level than Germany and displays moderate growth up to 1925, interrupted briefly by World War I. During the period from 1925 through the Depression and up to World War II demand declines. In the post-World War II era demand expands sharply to 1950 then declines to 1965. Britain starts low, though figures include only the public sector and would be somewhat higher if the private sector was included, but has rapid growth up to 1905. From 1905 to World War II there is essential stability, despite the establishment and slow growth of public secondary education. Taking the post-world war growth into account, the British pattern is quite like that of France since the


.8
.7
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1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
F
B
G
I
DEMAND FOR EDUCATION

Figure 1

turn of the century. Italy starts at the same place as Britain, has slower but exponential growth until World War II and rapid post-war growth.

The kind and number of periods we observe are the following: there is one for Germany and it is long term stability; there are three for France, moderate growth, stability, then a period of acceleration; there are three for Britain, accelerated growth, stability and then accelerated growth; and, there are two for Italy, moderate growth and then very rapid growth. And here we see the main advantage of using proportions of general variables transformed in various ways. The patterns quickly fall into a language that is useful analytically.

1. Lines parallel to the x axis are representative of stable periods;

2. Slopes represent periods of change;

3. Changes in slopes represent periods of changes in the rate of change.

The causes and consequences of stability and of change become the analytical problems.

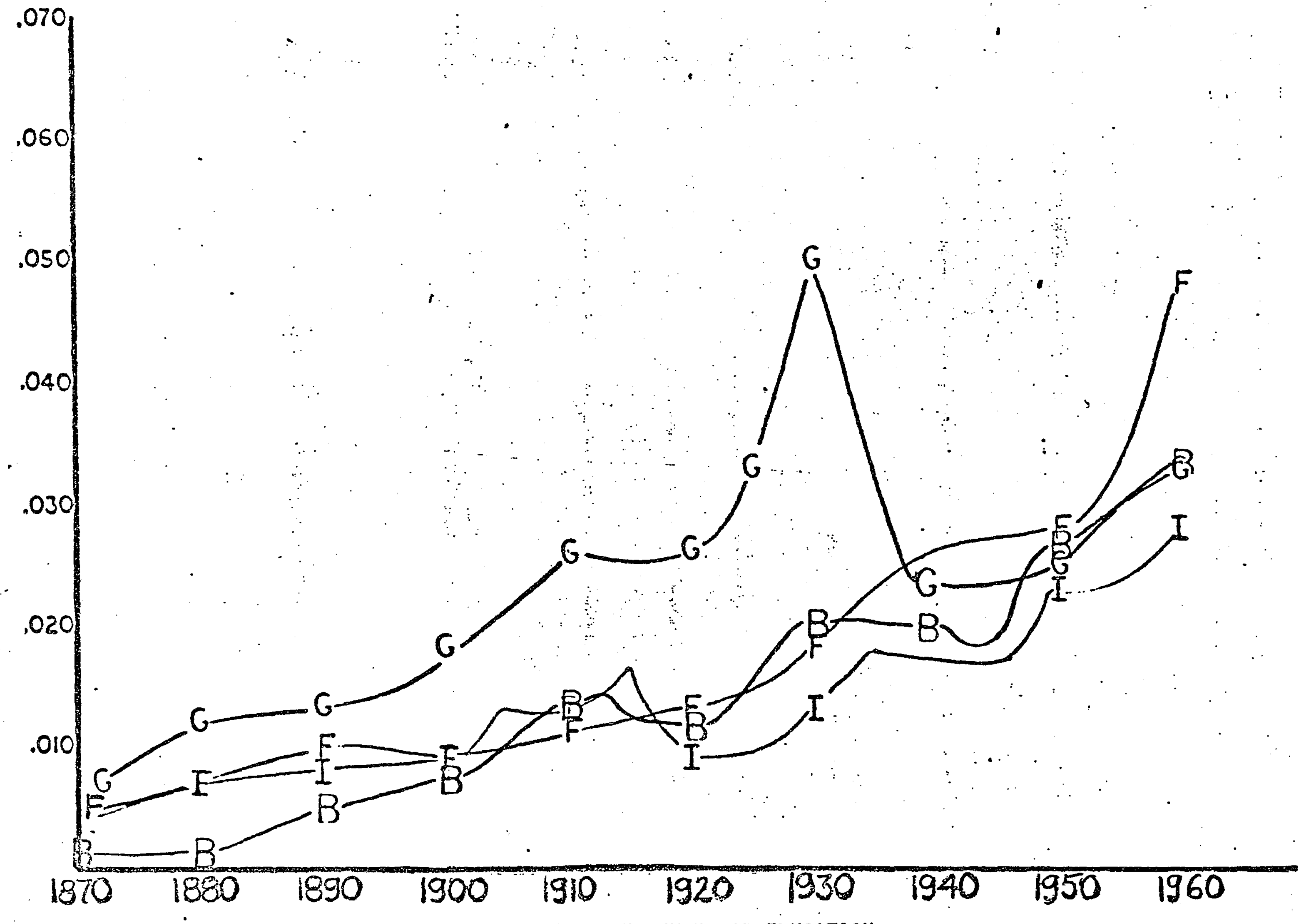
If we consider the line parallel to the x axis as stable and a nonzero slope as change, then clearly we have periods of stability and of change. Both require some explanation: what started the change period of growth in the first place, what has halted it, and how similiar are the trajectories of the four countries? These represent the discontinuities. This is the great intellectual advantage of comparative time series. The trace lines nicely isolate continuity and discontinuity, letting us perceive time periods that are the same and time periods that are different where none previously perceived them.

As everyone can immediately appreciate, our description and analysis revolves around the second derivative or changes in the rate of change, that is changes in the slope. This distinguishes, at least descriptively, quite distinct periods. But these distinctions raise two separate kinds of problems. The origin and major shifts in slope could be thought of as the historical problem whereas the periods of constant slope can be thought of as the periods for the more typical social science problems. One analytical issue is whether or not regression analysis should be contained within periods of relatively constant slope, a point that we shall return to in the next subsection.

Substantively the timing of the changes in the rate of change is interesting. Again one regards the long sweep of growth in British and French education in the 19th and 20th centuries, one is struck more by the irrelevance of legislation as turning points and the essential social and determined growth in demand for education that fits an incrementalist or creeping expectations model rather than any other. Although the accelerated expansion in education has been much noted in the post World War II period, its origins lie <u>before</u> the war. To periodize by the war is to miss the inflection or take-off point. And contrary to the economists who argue students are affected by rates of return, the take-off lies in the midst of the Great Depression. Only Germany appears affected by this. That is, there is a decline during the 1930s, but this occurs concomitantly with the economic growth. The decline probably represents the Nazis' dismantling of University education and the expansion of the armed forces. The interesting question is why does not Western Germany experience an acceleration as the other three Western European countries? Clearly Germany is marching in step with a different drummer. It is the long-term stability or lack of change that becomes interesting here. Descriptively then, our time series data has raised historical questions which run counter to some of the perceptions of experts in the area. But note that there are three requirements: the use of time series for a longue duree, standardized in an appropriate way, and juxtaposed vis-à-vis other countries in a somewhat similar state of modernization and of economic development. Perhaps everyone understands the necessity for standardization. The necessity for a long period of time and for comparative data are perhaps more controversial. Yet, changes in the rate of change have significance under these circumstances when comparison is made both synchronically and diachronically.

And for those who are concerned that by using general variables historical issues are lost to view, please note that one can make both general and particularistic statements. Germany's pattern is different. In the 20th century the three other countries experienced an acceleration in demand as we have defined it. In fact one can only understand the dialectic between the history and social science with general variables applied comparatively across time, otherwise there is no referent.

Perhaps another example is necessary. In Figure 2 we plotted the percentage of GNP spent in education across all government levels in the four countries. For Britain, there are essentially three periods. Very slow growth up to World War I. A step function after World War I with again essentially very little or no growth until the 1950s. After World War II, steady growth ensues. One is struck by the tendency for Britain to change by relatively discontinuous shifts and then stabilize, reflecting very conscious policy decisions. France has three distinct periods as well. Slow and undulating growth until a take-off in the 1930s. There is a violent swing associated with the war and then another take-off in the 1950s. Here again one could argue that the war was really an interruption in change that had already started to occur. Italy has a pattern somewhat like that of Britain except




ALL GOVERNMENT EXPENDITURE FOR EDUCATION

AS A SHARE OF GNP

FIGURE 2

the changes are less abrupt. There is slow growth with some undulations in the between war period and then acceleration in the post World War II period. Germany has a distinctively different pattern. There is a gradually accelerating growth that stops with the first war period. When the Social Democrats are in power, there is a violent swing associated with the large decline in GNP and a steady decline during the Nazi period. Then in the Bundesrepublik there is slow growth. And here we observe a deficiency of our method of using proportions: Violent swings in the denominator change the proportion considerably. In general, proportions dampen violent changes but they do not eliminate them completely. Sometimes the changes in the rate of change represent artificial changes in the denominator. But note that when making comparisons between countries and assuming comparable shocks, we discover that the systems handle them in different ways.

Although we do not have the time to explore the meaning of these different patterns, the hope would be that specific ways of responding on the part of the governments or societies would represent distinct characteristics. For example, it may be that the incrementalist image fits a society with a large entrenched bureaucracy (Wilensky 1975) whereas a pattern of more sudden shifts may be more characteristic of societies with strong local government. Regardless, the ways in which slopes change creates a new datum worth analytical attention.

When the demand and supply plots are compared several rather interesting points can be made. Despite our consideration of costs per student, the growth in public expenditures for education has been most rapid in the post-World War II period. How much this can be defined as a catching-up period is questionable. We only observe that the creation of a production function for education offers some rich possibilities for analysis. Our own interpretation is that education has become quality conscious and technologically intensive during the past 30 years and this more than the growth in demand explains the far faster cost rise. What is equally apparent is that two countries--France and Germany--provide relatively more and two other countries--Britain and Italy--relatively less, at least for the period being analyzed. This is especially striking given the relatively greater effort in the private sector in Britain while the French figure includes the cost of most of the private sector, which is presently being underwritten by the central government. Admittedly, since 1965 these figures may be changing.

Once the resource allocation problem has been conceptualized as one of demand, supply, and responsiveness under conditions of changing technology, a series of interesting new issues arise. The core of our analytical thrust is around the issue of disequilibrium and equilibrium; the match or mismatch between supply and demand. Before the disequilibrium questions can be usefully analyzed, however, some additional issues regarding supply and demand must be resolved.

Algebraically, the difference between demand and supply at any point in time is a measure of unmet need.

$$N = D(t) - S(t-1), \qquad (1)$$

where N is need, D(t) is current demand and S(t-1) is existing supply. In cybernetic theory, equation (1) is called an error function. It tells how close the system's actual state is to some goal. In this case, the desired state is the percentage of a cohort being educated, D(t), and the actual state is the percentage of GNP spent on education, S(t-1). Clearly these two quantities are not in the same metric. Subtraction of expenditure from people will not produce a meaningful quantity. We have two choices here. If we are interested in expressing needs in terms of students, then we must multiply expenditures by the percentage of the cohort that can be educated per percentage GNP spent. Ignoring time and concentrating on the metrics we have

$$N(\text{students}) = D(\text{students}) - S(\%GNP) \cdot P(\%\text{students}/\%GNP), \quad (1a)$$

where P stands for productivity, the percentage of students that can be measured for a given percentage of GNP. Since units of measurement cancel algebraically, the (%GNP) units on the right cancel S leaving demand, supply, and need expressed in (%students). But our interest is in stating need in terms of expenditures. For this we must multiply demand by the (%GNP) that must be spent per student.

$$N(\%GNP) = D(\%\text{students}) \cdot 1/P(\%GNP/\%\text{students}) - S(\%GNP), \quad (1b)$$

where 1/P stands for the inverse of productivity or cost per student. Now (%students) on the left hand side cancels and we can express distance from a goal (meeting demand) in expenditure units (%GNP).

Had we chosen to model demand in a more complex manner, for example, as some function of rising living standards, cross-generational mobility aspirations, increased needs of technical advance in industry, etc., it would still involve some final computation in terms of actual students to be educated. In an open educational system, however, the percentage of the cohort actually being educated will prove a useful first approximation of demand more subtly defined. A more important point here is the use of productivity as a conversion metric.

Educational technology is important here in that it determines the number of students that can be educated for any given committment of resources. Its definition allows us to translate demand for educated students into expenditure necessary to meet these needs in a meaningful way. The percentage of a cohort being educated divided by the percentage of GNP allocated to their education (demand/supply) is the normal measure of productivity, that is, output divided by input. Productivity is not an adequate measure of technology for a number of reasons. In the short run, the major way for the education system to meet increased demands is to increase productivity. This would normally be thought a crisis period with student/teacher ratios increasing and, potentially, the quality of education decreasing. Eventually limits to physical capacity would be reached. If the system is operating at maximum capacity, the only way to meet new demands is through increased expenditure. This will, depending upon magnitude, be looked at as somewhat of a crisis by government.

Against this short-run cycle of pressures for increased productivity and increased expenditure induced by demographic cycles is a secular increase in the quality of education, that is, the percentage of GNP spent per percentage of cohort being educated. It is this long-run trend that is most relevant for determining demands that can be effectively met because at any one point in time the educational system and the government may be trying to work out of a short-run crisis. Productivity will eventually decrease as the crisis passes.

In a fixed technology (productivity) situation, need can be met only through decreasing demand or increasing supply. Over time, changes of supply in response to need can be conceptualized as

$$S(t) = 1/T[D(t)\cdot(1/P) - S(t-1)], \qquad (2)$$

where T is the number of years delay in meeting needs. In words, a 1/T% of need is met per year in the form of new supply (expenditure), S(t). At any one point in time, T can be estimated by

$$[D(t)\cdot(1/P) - S(t-1)]/S(t) = T(t), \qquad (3)$$

derived from algebraic manipulation of (2). Under the circumstances where both productivity P, and delay in new expenditure, T were constant: the new supply level S(t) could be computed mechanically. But it is more likely that delay is a function of unmet need. When all demand is being met, delay will be infinite--no new supply is needed. But as needs go unmet, there will be strong pressures to reduce delays in providing expenditures. Later in the paper we will test a model that accounts for these delays. At present, we will simply attempt to describe the delays and how they vary over time.

Before delays can be estimated, however, we must take out the long-run technological impact that is certainly a factor affecting productivity and thus effective demand over the 100-year period we are studying.[2] A general way to do this is to estimate change in expenditure per student as a function of time. If there is no trend, productivity, **P**, is constant and we have a fixed technology situation. The reality, however, is otherwise, albeit with differences between our four countries. Regressions of cost per student as an exponential function of time show it growing at 1.8 and 1.2% per annum in Great Britain and France, respectively, with Italy growing at 0.7% per year. Germany, on the other hand, shows a decrease of 0.2% per year--with a standard error of .69; however, this is best interpreted as a constant. Whether these changes reflect relative efficiency, improvement in quality, etc., cannot be determined from the trends alone. We can inquire into the sources of the trends by computing expenditure per student as a function of students at the primary, secondary, and higher levels, since costs and technology are different at each level. Great Britain and Italy experienced the greatest increases in cost per student at the primary and secondary levels while in France it has only been at the secondary levels. The constant productivity of the German system was essentially the result of keeping the growth of the primary level and increased expenditures in balance. Since we have standardized cost per student, these results are not affected by cohort sizes but rather reflect decisions regarding expenditure and access to various levels of education, decisions based on different policies in each country.

Now that we have accounted for changes in cost per student (leaving aside any discussion of underlying policy), it is clear at least that for three of the countries we do not have a constant technology situation. Thus to investigate delays in meeting effective demand (expenditures demanded under existing costs per student) we must rewrite equation (2) as

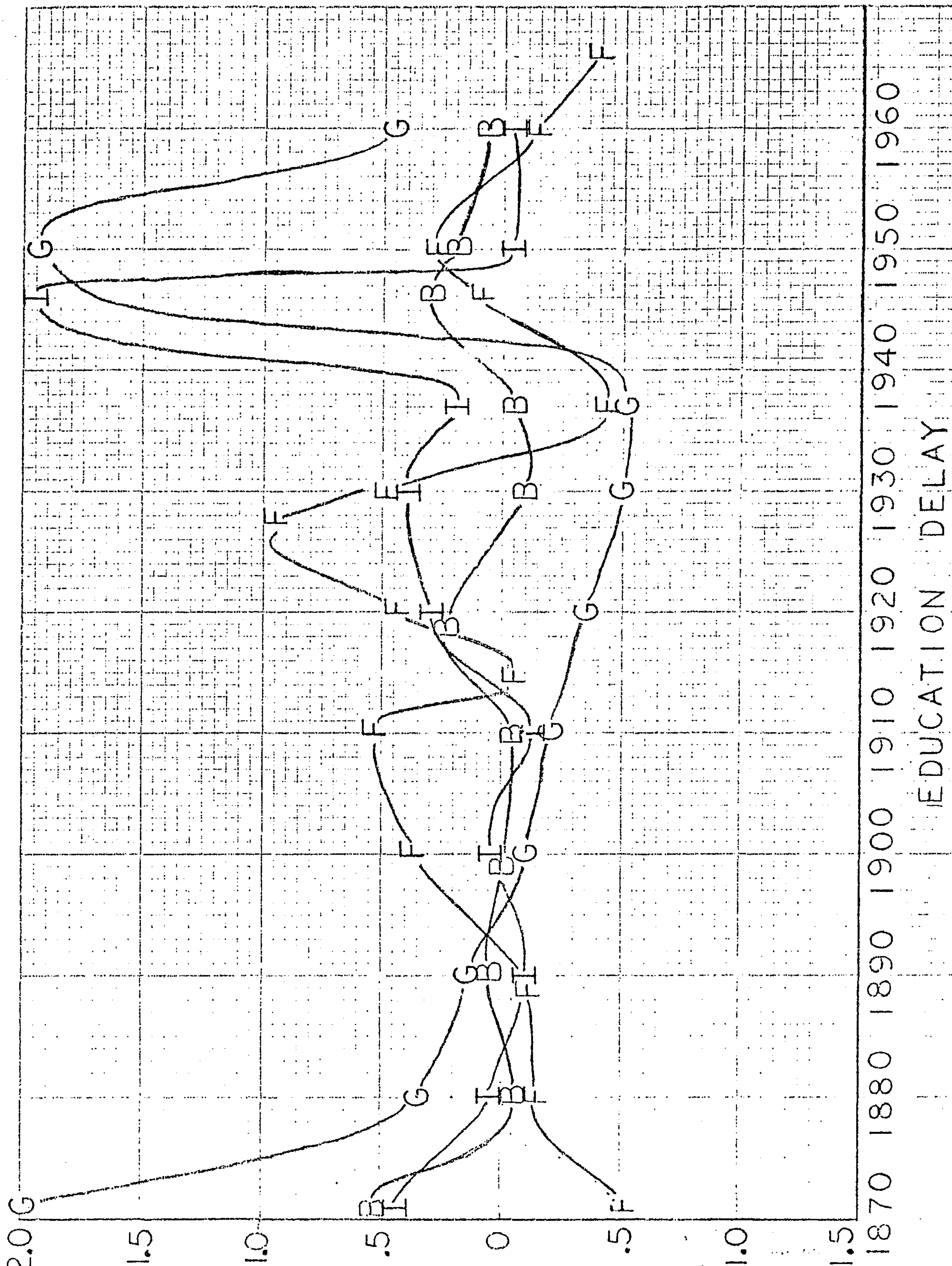
$$S(t) = \left\{1/TD(t)\cdot[1/P(t)]-S(t-1)\right\}, \tag{2a}$$

where P(t) is understood as productivity (the inverse of costs per student) as a function of time. Our calculation of delay then becomes

$$T(t) = \left\{D(t)\cdot[1/P(t)] - S(t-1)\right\} /S(t), \tag{3a}$$

allowing us to compute delays at any time point corrected for overall changes in cost per student. This equation is computed for each country and plotted in Figure 3.

Delays in Figure 3 are expressed in years. Delays greater than two years around World War II fall off the graph and are clearly periods of secular disequilibrium. The pattern is quite clear. After initially different starting points in 1871, the countries converge to equilibrium in 1890 and from there follow different courses until World War II. Initially, Great Britain and Italy start out at roughly the same position, a one-half year delay in meeting productivity corrected demand, that is, effective demand. Germany starts at a two-year delay and France is spending in excess of its effective demand. The significance of these initial differences


2.0
1.5
1.0
.5
0
.5
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1.5
+
-
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
EDUCATION DELAY

Figure 3

should not be exaggerated without evidence of productivity trends from earlier periods: the regression fit of costs per student as a function of time can be assumed less accurate for earlier periods. The equilibrium convergence at 1890, however, coinciding with economic trends is certainly a conjuncture worth careful historical scrutiny - an interesting task, but beyond the scope of the present paper.

The movement away from equilibrium after 1890 starts a clear period in the development of European education marked by differences between the countries. Delays in France begin rising to a peak of one year in the 1930s while Germany, until World War II, replaces France as the country spending ahead of effective demand. Delays in Italy remain constant until 1910 when they begin increasing, but only to a peak of one-half year (a return to Italy's 1870 position) in 1930: Italy returns to equilibrium thereafter. Britain has periods of instability after World War I and World War II but is generally cycling around equilibrium at other times. It should be emphasized that these are relative comparisons. The absolute levels of productivity or cost per student (percentage of GNP spent per percentage of cohort being educated) are different across the countries reflecting the different organization of the education systems. Again, this is another fruitful area for study that will not be pursued here but which would be necessary to make any absolute comparative statements.

We can further estimate average delay for each country by computing a regression coefficient for equation (1). When inverted, the coefficient indicates average years to reach equilibrium. In France the time delay is 5 years, in Britain 1 year, Germany 1.1 years, and in Italy 0.7 years. The computation differs somewhat from the visual picture due to the well-known effect of outliers on biasing regression estimates. In this case, the relatively different dislocations of World War II contribute to the discrepancies. Better estimates would result from exclusion of more years around the wars. On the other hand, the residuals at this point provide interesting quantitative evidence of relative dislocation in the education system experienced in each country.

In attempting to account for delays we compute equation (3) as a function of variables believed to affect rapidity in meeting demands. Since delays are not constant over time, this is equivalent to asking why government and the education system are more or less responsive during certain periods. While this is an old question, the advance being offered here is in being able to provide a quantitative and comparative answer. Two variables must be included in any delay model which attempts to handle short-run behavior. First, we have already mentioned productivity. In the short run, this is the easiest way to meet demand without creating a delay: educate more students for less cost. Second, the accumulation of past differences between supply and demand or unmet demand is an important variable. Presumably it takes time for needs to enter awareness, and action to reduce delays must be a function of higher awareness. While productivity change and unmet demand must be included for realistic dynamic behavior in any explanatory model, they do not explain the conditions under which delays are most likely to be reduced during a given period. Other variables must be included. One of a number of models we are considering predicts delay as a function of centralization, the latter measured as percentage of all government expenditures accounted for by central government, legislative effectiveness, parliamentary representativeness and duration of the executive.

One might argue that the delay or disequilibrium or mismatch between supply and demand, however interesting, is just relevant to our intellectual concerns. In the next section we suggest a number of other kinds of variables that have many of the same properties and which are relevant to a vast array of intellectual concerns.

The use of changes in the rate of change as a way of delineating periods is a relatively simple procedure to employ and offers a set of analytical problems. However, to be successful one must follow the general guidelines which we have tried to establish in the previous section.

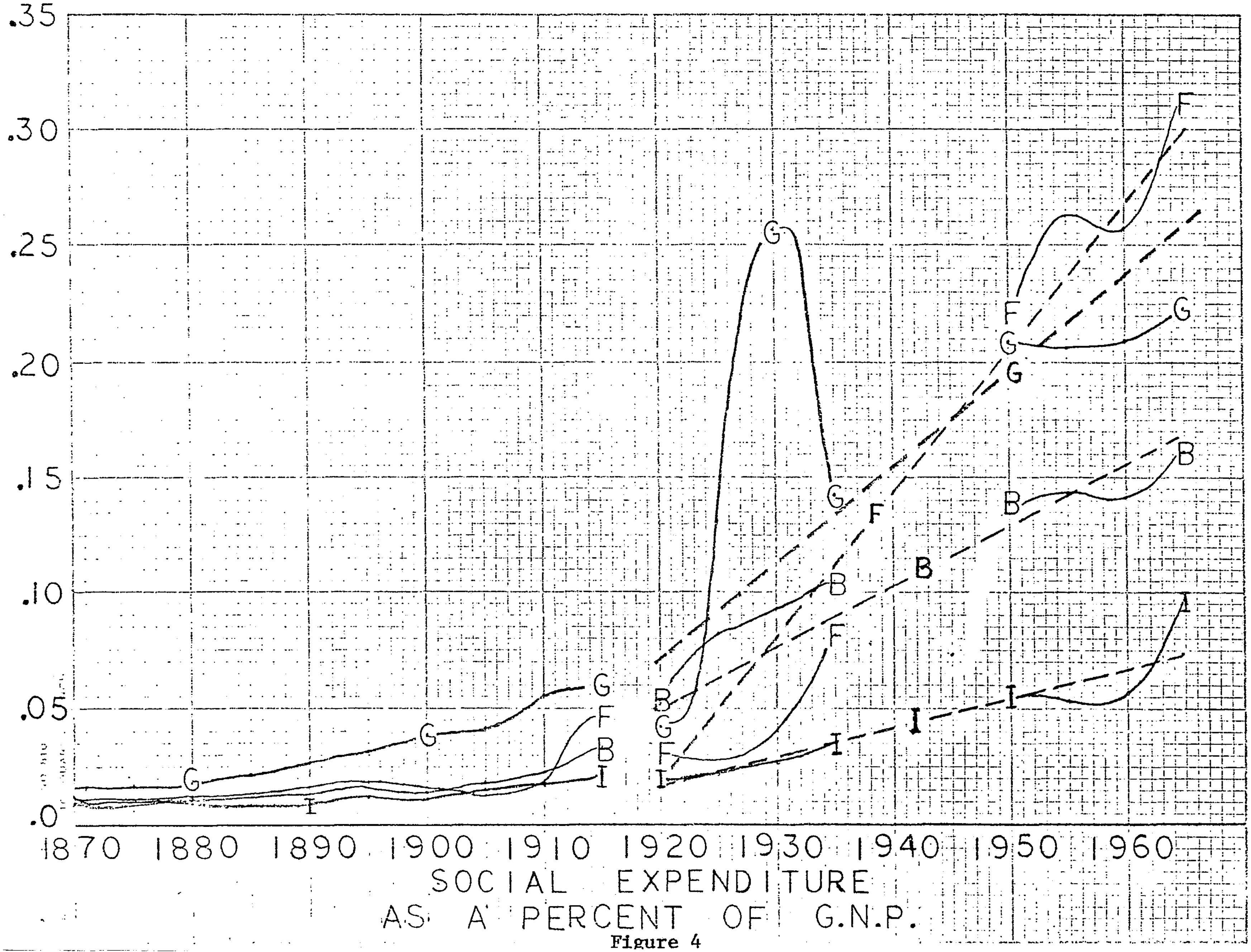
If one has proportions of a general nature, then the interpretation of stability and change and of changes in the rate of change is quite simple. These kinds of variables allow for transformation whether linear or nonlinear in a quite straight-forward manner and have an ease of interpretation in regression analysis.

## The Use of a Regression Equation

We have so far discussed the delineation of periods by using time series data but there are other ways that offer some interesting descriptive and analytical possibilities. Suppose we start with the idea that a period is characterized as a certain trend, a period of internal logic where the slope is the same. Under these circumstances, the best thing may be to fit an equation as a function of time. It does not need to be linear but could instead be log-linear or more complex polynominal depending upon the phenomenon at hand.

Theoretically, the best way of conceptualizing the periods of a country is to recognize two components: the long-term trend, which focuses on periods characterized by changes in the slope or the second derivative and the swings or fluctuations, which can themselves be a distinctive period or represent variations about a general tendency. The theoretical reason for this distinction is simply that the causes of the general trend and the causes of the swings can be and usually are quite different. Thus economic factors might be quite critical in explaining fluctuations in birth rates--the baby boom or bust--but not have much influence on the general long-term decline in birth rates, which might be more a function of rising levels of education, better technological control over fertility, declining infant mortality rates and the like. It is also true that not all variables have both long-term trends and swings as is characteristic of outputs, but in general measures or estimates of demand or need do. Yearly measures in most cases avoid seasonal fluctuations, which are of little interest, and yet allow for a sensitivity to both turning points when a new period or slope is established and the fluctuations or swings if they should occur. Again, note how the number of time points becomes critical for understanding the problem.

If one regards the longue duree of social expenditures (see Figure 4) in the four countries, one is struck by the relative constant increase in the public expenditures on health, welfare, housing and various kinds of social security programs as a percentage of GNP. Indeed, one is able to fit a regression line as a function of time with a reasonable degree of accuracy. This is perhaps a surprise when one considers the existing literature (Peacock and Wiseman 1961, Musgrave 1969, Andre and Delorme 1972) that has tended to emphasize the shift that occurs immediately after a war. If, however, one does not accept the conventional periodization of wars and depressions then we are struck more by their representing nothing more but


.35
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I
SOCIAL EXPENDITURE
AS A PERCENT OF G.N.P.

Figure 4

temporary interruptions to the long and relatively continuous climb. An inspection of the period prior to the 1870s and 1880s in Britain, France, Prussia and the Kingdom of Sardinia indicates that social expenditures as a percentage of GNP remain quite constant throughout the period prior to 1871. O'Connor (1973) in a recent book has suggested that there is an impending fiscal crisis because this proportional increase cannot continue indefinitely. Previously the demands of all classes have been met. Indeed, we have included education together with health and welfare, precisely because they are seen (Wilensky 1975) as representing the interests of different groups. If so, then the next quarter century should be of interest because it would appear that the time of hard decisions about whether more taxes or income, social security or risk, inflation or income control, etc., are upon us. The advantage of fitting a regression line as a function of time then is that it allows us to very simply define a major trend and to also provide some simple solutions to the ideas of trend and of swings about a trend.

If one has a relatively long period of growth, then the analytical problem is to understand when there are deviations from the particular function that is fitted. The real issue is to explain the residuals where a regression line is seen as the general trend.[3] It is here that political variables can be so important. They can change the slope of the process, which is to say the general trend, therefore changing the patterns of residuals. Political parties like to remain in power. Ideology about societal priorities may result in hesitation given a crisis but not necessarily inaction. Hesitation reflects itself in a larger residual. Thus the residuals have their own descriptive value. Any long-run correlation between party in power and public expenditure is bound to be zero because parties want to stay in power. Programs have statutory requirements that cannot be easily manipulated, frequently ones ties into GNP, which is why one wants to analyze deviations from trends in public expenditures as a percentage of GNP. But parties in power can affect interpretations of statuatory requirements and be more or less eager to change them and it is this that affects changes in the percentage of a nation's income allocated to public expenditure.

The fitting of equations as a function of time and then the analysis of the residuals thus forces us to analyze periods in two ways: as an evolutionary trend at least for a certain era or period and as swings and fluctuations about that trend. The trend can be linear or log-linear or even curvilinear. It can be made specific to each country or even be made more general.

For example, in some recent work (Bairoch 1977) on the growth of GNP in Europe during the past two centuries, the growth rates of particular countries are compared relative to the overall performance. This way of conceptualizing periods, that is whether a country is going faster or slower relative to the general tendency also creates a set of new analytical problems, one where again there is an implicit assumption of a world pattern of growth or an inherent stage of growth and the issue is why some countries are moving faster and others slower relative to this standard. While treating the average as the norm raises a number of delicate issues as to which countries are added together and whether certain ones can be compared, it again calls attention to the importance of deviations as a critical way of conceptualizing periods. And it is here too where political and social variables are much more likely to be important than economic and demographic ones.

Which countries are combined of course raises a number of critical theoretical issues which we cannot address here. Our own rule for our set of problems, namely the adaptiveness of society, has been to control for all of the essential resources, namely the level of economic development, power, modernization, population size, and the same geopolitical area of the world because each of these resources or factors could affect adaptiveness. Combining countries of varying size and comparing their economic growth as has been done may not be wise because of economies of scale.

In summary, we have suggested that continuous time series can be employed to delineate periods in several different ways. The changes in slope or second derivate can be considered as the periods. This is especially helpful when the data are proportions that are general and therefore can be compared diachronically and synchronically. This solution can be used even with variables such as party votes, that do not occur annually if proper estimation procedures are used. Another approach is to fit an equation as a function of time specifying this as a trend and then analyzing deviations from the trend as swings that also require an explanation. The use of these approaches moves one away from the temptation to perceive dramatic events as bench marks but instead changes in the rate of change or deviations from trends as the main discontinuities while the slope or the trend are the continuities. Both require explanation but their causes can be quite different. These methods allow one to note similarities and dissimilarities between countries and eras and thus in another way speak to both social science and history.

We have not addressed the issue of when does one choose which method. Each has certain analytical advantages and disadvantages. The first method focuses more on changes and may create too many for meaningful analysis.

Clearly, if there is change of slope every three years, we might prefer a method that would give us more order in the data. The second method focuses more on the consistency of trends and may obscure meaningful slope changes. Note that the dialectic here is essentially between the pattern of residuals and the stability of the change in slope. The longer the latter remains constant the more one wants to use the first approach to periodization and the more there are fluctuations and especially on both sides of some regression line, the more appropriate the fitting of a regression line as a function of time is as a method for delineating periods.

## 3. PERIODS: THEIR ANALYSIS

If one takes a large number of variables and describes each of them by periods, the sheer amount of descriptive material would be overwhelming. There is a need to find some more global statement. However the shift from determining significant periods along a particular dimension to determining significant periods among a number of dimensions raises additional problems besides the descriptive one.

### The Problem of Auto-correlated Error

The most well-known difficulty is auto-correlated error. In serial correlations there tends to be a greater opportunity for the error terms to be correlated across time. There are a number of reasons why this is so. The data is collected frequently by the same agency within a government, e.g., a statistical bureau, and they tend to make the same errors in the way in which it is collected. The possibility for other variables that are unknown to be correlated is much greater with time series data since assumptions about randomness are more plausible with cross-sectional data.

There are also some misconceptions about time series data and the magnitude of the problem. Anyone who has studied time series data becomes impressed with how frequently unpredictable events do occur. Governments change priorities. Crises such as energy shortages or food surpluses or wars happen. Perhaps even more telling is the fact that there is a large and popular intellectual school of thought especially in Europe and particularly in France (Verhaegen 1974) that argues against the possibility of any social science because of the unpredictability of history. The more that one accepts this perspective the less difficult is the problem of auto-correlated error in time series data. Of course, usually these individuals deny the utility of doing any regression analysis. What they have failed to recognize is how historically specific most of this work is. In any case, time series data is much more random than commonly assumed albeit probably still less random than some cross-sectional sample. Also we might add that in the longue duree the problems of correlated error tend to diminish. Agencies change their methods of collecting their data. There is greater opportunity for random events to impact and "all other factors" are changing at different rates and with different rhythms. For the short-term, say a span of 25 years, the problem of auto-correlated error in serial correlation can be quite great but this diminishes with the passage of time, that is more data points.

To diminish the problems of auto-correlated error in time series data, we have advocated creating variables such as delays. Since these undulate in nonrepetitive ways, they avoid most of the problems associated with the more traditional variables studied such as urbanization and industrialization where the possibilities are greater for auto-correlated error.

But everyone is not interested in delays. Are there other variables such as these? Almost any problem can be conceptualized as stimulus and response as the psychologists have argued in their very general paradigm. Responses can always be considered in terms of their adequacy, which is our definition of delay, and their quickness, which is, of course, time lag. For example, Easton's paradigm which has been much criticized as being too general can be conceptualized and quantified as follows. Swings in opposition vote represent a stimulus to the party in power. Do they respond with changes in their priorities vis-à-vis various expenditures categories? Again we have a delay which can be called extent of response and one that can change over time. We are presently exploring this in our data analysis and our preliminary results are quite suggestive. Among other findings, the longer the duration of the executive in power beyond a minimum of four years, the bigger the delay or lack of responsiveness to swings in opposition votes.

Another category of variables that have both theoretical merit and statistical facility are what might be called balance or ratio variables. We all know that industrialization and urbanization are highly correlated. But suppose we create a ratio variable between these variables. We now have something that is much more interesting and a new set of problems. What causes imbalances and what consequences do these have? Flanigan and Fogelman (1968) explored this in a very suggestive way in their work on political development; however, their essential insight about imbalances has not been rigorously followed up. Imbalances or ratios between variables represent a whole set of "new" data that can be easily generated. They allow for the exploration of equal finality, that is, different systems of societies in this instance can evolve by different pathways. Equally relevant is some of their suggested findings about rapid rates of change producing instabilities. These suggest both the usefulness of employing periods defined by changes in the rate of change and at the same time that different slopes will have different relationships with other variables, that is the connections are nonlinear.

We believe that one of the most interesting ratios is between industrialization and modernization because of the very striking differences between the growth of industry in the four countries that we are studying. Contrary to those who argue that educational investments, which is our measure of modernization, stimulate growth, we believe that money invested in this area means less capital investment in industry. Furthermore, industrial expansion probably does not need much skilled labor especially in the beginning stages. Regardless of whether this argument is correct or not, creating ratios between industrialization and modernization opens new analytical possibilities for describing periods and at the same time for avoiding the problem of auto-correlated error.

Consistent with our discussion in the previous section is the idea that pooled time series data reduces some of the problems of auto-correlated error. One introduces more variation in the "other factors" and reduces the influence of some third factors that might be correlated with the error term but only in a specific country. If one does accept the idea that there is more variation by country than by time and especially for short durations such as 25 years, then one increases randomness by pooling several countries and especially over the longue duree.

Pooled time series data is still a relatively new technique and is presently being explored by econometricians but it does offer--it seems to us--rich possibilities. For example, centralization of a society as measured by a political development index may not change very much. By pooling several countries one can then study the impact of a relatively static phenomenon. It is our hypothesis that centralization may well determine the adaptiveness of a society (Toynbee 1946), that is more centralized societies will have larger delays and these will tend to dampen more slowly. Regardless, the pooling of time series data does considerably increase the amount of variation and reduce the problem of autocorrelated error.

Thus, there are a number of ways of handling the problem of autocorrelated error in time series data. More serious to our way of thinking is the problem of parameters changing across time. This appears to be the more fundamental issue but one which at least appears to have a solution that is viable.

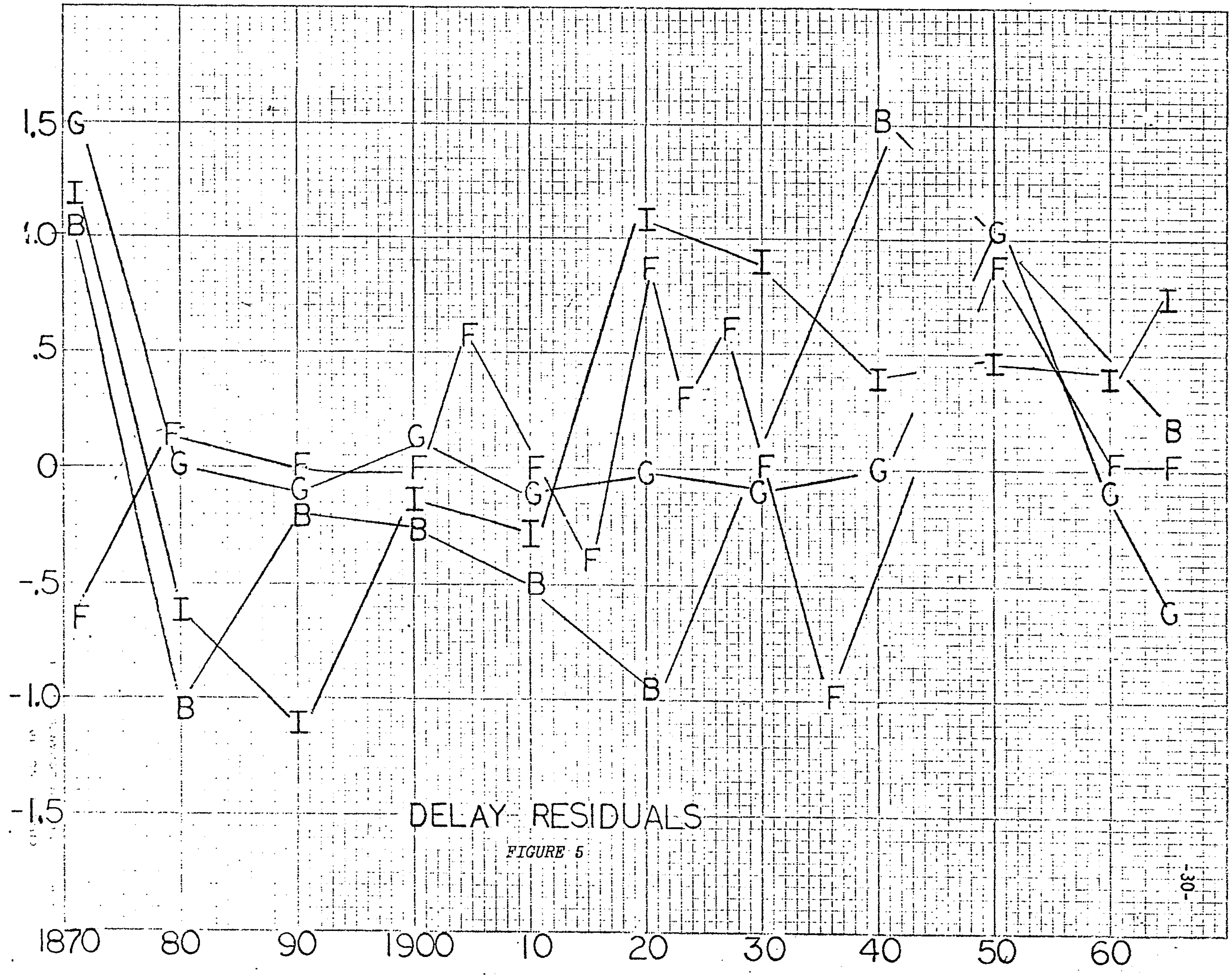
## The Use of Parameter Changes as the Delineation of Periods

In the previous section we suggested that estimating demand for educational expenditures was difficult because describing the relationship between the proportion of the target population in school and the need for funds was altering as a function of modernization. If one cannot measure this or the other factors that may be predicting the changes in the parameters, then it means that the relationship between this variable and other variables will gradually or perhaps even abruptly break down since the particular number is no longer relevant. Similarly, Delorme and Andre (1972) found that elasticities between changes in student populations and increases in government expenditures were different in different periods. However, their designation of periods was on the basis of the convention 1871-1914, 1921-1939, and 1946-1971.

In the cliometric work of Williamson (1974), the parameters estimated in the 1870s for a general equilibrium model of economic growth of the United States worked reasonably well until World War I. If one examines the large literature on the status attainment model, one is struck by the changes in betas. Finally, if we reexamine Figure 3, it is clear that the delays are decreasing with time. This is another way of stating that the time lags are diminishing. One could add other evidence but all of it suggests that the parameters--betas, exponents, time lags--are altering and not simply as a function of time.

Our approach is to examine the residuals of any equation that we write or estimate via regression analysis, to see if the pattern of residuals indicates that the parameters are changing over time. The residuals for the relationship between delay in educational demand and centralization as measured by a political development index and the ratio of central government to total government expenditure are shown in Figure 5.

This particular model is not the most powerful one in terms of variance explained, yet it does reveal some interesting differences among the countries. First, there is no very important relationship between accumulation of unmet demand and delay. Both increase together. Apparently, the countries are not monitoring these variables. Productivity, on the other hand, decreases delay in all countries except France--the partial correlation being around .50. Centralization turns out to be an important explanation of <u>increasing</u>




DELAY RESIDUALS

*FIGURE 5*

delay in Italy and Great Britain, but solely because of the association of centralization with dislocation during World War II. In France and Germany, there is no association. The residuals from these regression models, that is, the difference between predicted and actual delay are plotted in Figure 5. Generally the model works best for the equilibrium period during the late 19th century. For Germany, productivity changes alone appear to be an adequate explanation for educational delays up to World War II. For France and Italy, the model predicts more delay than is observed during the early 20th century; for Britain the model predicts less delay than is actually observed until right before World War II, when more delay is predicted. The residuals suggest that we search for other negative or positive feedback loops that were operating during particular periods. If more delay is being predicted by the centralization model, as is the case during the early 20th century in France and Italy, we can ask what factors kept delay as low as was actually observed. Other models we are considering indicate some impact from interest group formation and political variables as other sources of control on delays.

This leads to still another way of characterizing periods in a country. It is done by saying that when the relationships across time remain relatively constant, that is the estimates of the parameters are reasonably good and there is normal variation in the residuals, we have a particular period. In other words, we advocate reversing the normal procedure, which is to pick the periods and then compute the parameters within each of these periods. It seems preferable to estimate the parameters first, however crudely, and then define the periods. If one finds the residuals homoscedastic for certain chunks of time, then that era can be characterized by the slope or slopes of the key causal variable. Note that this procedure will work with any number of variables whether combined linearly or nonlinearly.

The simple rule then is to always inspect the residuals. They provide a wealth of information that can be used to generate not only new ways of seeing periods, but of providing new problems to be analyzed. If one finds major shifts then we recognize that the parameters must be reestimated with the appropriate time period. This is not quite the same as eliminating deviant cases such as the extremes produced by the shocks of war or great depressions. These shocks are usually temporary disturbances (as we have suggested repeatedly throughout this paper). Normally one would exclude these periods completely as we have done for 1939-45 (and then we only did this because France was occupied by Germany; we felt it had lost its independence) or ignore them as we have done with the great depression and World War I.

Space does not permit us to explore whether particular patterns of residuals represent specific parameter changes, that is whether the changes in the betas, exponents, or time lags have characteristic residuals. But this does seem like a useful avenue for future methodological work. This represents a whole new set of time series data that should be collected and reported: the parameters in major equations over time. Please note that this could be done for particular countries or for a group of them in pooled time series data. Which option one would select depends upon how historically specific one perceived their equations to be and the particular analytical interest.

To generate this kind of data, however, we must reverse our normal way of thinking about historical periods. We should try to generate equations that will work for the longue duree, estimating the parameters as best we can, and look for the goodness of fit, letting it delineate the meaningful periods for us. It should move us naturally closer to writing equations or developing computer simulation models. It would force us to be more theoretical and less ad hoc in our data analysis. As we study the residuals we would obtain insights about our theory, model, or set of equations that are unlikely to come if we rely solely on machine estimations. This is all to the good!

However difficult this may appear to be, it is less so if we seize the intellectual opportunity presented by this seemingly impossible hurdle, namely finding variables that predict the parameters. If we agree that they may be changing as a consequence of particular variables and not randomly then the parameter changes are possible to predict.

In our discussion of estimating the costs per student for demand for public education expenditures we suggested that modernization may predict changes in this. If one can identify which variables influence the betas, the power terms, and the time lags, then one can write a set of equations that would generalize much beyond the immediate historical era as detected by the residuals. This seems to us one of the major ways in which social science is quite different from physical science; the parameters change over time as a consequence of human activity. It remains to be seen whether these changes can be predicted or at least post-dicted.

This is one reason why we have placed so much emphasis on creating variables like delays because they lead quite naturally into an analysis that is sensitive to the issue of shifting parameters. Descriptively if we see that delays are decreasing as a function of time and we then find some correlates with this, say such as the lag of communications, then we can begin to explore whether this variable predicts time lag. Likewise, we have suggested that centralization may explain the speed with which government or societies respond to changes in demand. The role of political parties à la Easton can be seen in the same light. Political variables may operate more as accelerators or decelerators of the economic processes of supply and demand. If so, then we have not only combined economics and political science in a more satisfactory way but we have generalized equations considerably.

## 4. CONCLUSIONS

We have tried to remain faithful to both the topic of how to create meaningful historical periods or societal eras and finding new sources of data. The problem is usefully seen as both a descriptive and analytical one, both theoretical and methodological. Periods can be delineated by changes in slopes, that is, the second derivate, along some critical dimension or they can be determined by changes in the parameters defining the relationship between two or more variables. The two are not necessarily related, although changes in slopes can produce residuals that are larger than average because of time lags. Trends can be described as functions of time; the residuals created represent swings about the basic trend. This is especially helpful when the phenomenon appears to be changing at a constant rate over a relatively long time span. Then the analytical problem is to explain booms and busts.

Conceptually the creation of delays, ratios, imbalances and the like represent a new source of historical data. They also avoid most of the serial correlation problems usually discussed in time series analysis. At the same time these variables help the researcher in his or her exploration of what might be key variables for explaining why the parameters in structured equations might be shifting or even predict the direction they may take in the future. Theoretically, delays, ratios and imbalances speak to a vast array of intellectual problems in history and the social sciences. They allow us to understand disequilibrium, equal-finality, adaptiveness and other abstract concepts that up to now would have appeared to defy quantification. They lead quite naturally into dynamic thought and thus that larger problem of process that remains at the heart of so much historical thought. Thus they merit our attention.

NOTES

[1]This particular age category corresponds to one that is readily available in most countries and is the appropriate one for primary, secondary and to a lesser extent higher education. Only in Scotland do primary grades start at age five. Primary school has been defined as ages six through eleven, secondary as ages twelve through eighteen and university as nineteen and above when attendance in particular kinds of schools was not known. The primary levels in lycees, colleges, have been included in primary education, cours complementaire and ecole primoire superieure as secondary education. By standardizing on the relevant cohorts, one avoids the problem of sharp changes in school population as a consequence of demographic change as occurred in France after World War I and in Germany after World War II.

[2]We are attempting here to develop a justification for the statistical procedure of detrending (Rao and Miller 1971, Section 4.6) through the definition of demand and supply and through the definition of technological progress in education. Two methodological procedures are commonly used for detrending: 1) detrend the individual variables, or 2) enter time as an independent variable in the regression equation. The purpose of detrending is to avoid spurious correlation among variables with similar functional forms over time. Exponential growth of economic variables most often comes to mind in this context. For historical analysis, detrended data focus on historically specific, transient phenomena. Trend analysis (see the following explanation of cost per student as a function of time) focuses on the long duree. We have chosen to detrend demand rather than include time in the regression equations that follow for ease of interpretation. We could also have multiplied the entire demand series by cost per student computed as a constant in 1871 and then entered time in the regression model. Results

from both procedures are equivalent (Rao and Miller 1971, p. 103). The former provides easier exposition while the latter proves less costly.

[3]The residuals provide many important sources of information in time series analysis and must be treated visually for maximum insight (Rao and Miller 1971, Chapter 5). Further uses are: 1) the location of transcription errors in the data; 2) identification of omitted variables--this must be done by comparing residuals with trace lines of variables one might like to include in a model; 3) identifying heteroscedasticity, that is, trends in the <u>variance</u> of the residuals; and 4) testing for serial correlation. The possibility of deciding the latter two points either from available statistics or from visual inspection appears quite remote and open to misuse. As a practical matter in the development of causal models, the first two uses are of the most value. Additionally, one can compare residuals using the same regression equation but changing the functional forms of the variables (Rao and Miller 1971, p. 105). As long as equations are properly scaled when transforming the dependent variable to nonlinear form, the equations producing the smallest residuals indicate the empirically correct model. Successful use of the technique, however, requires prior theoretical justification based on predictions of the partial derivatives of the included variables. Note that the linear model is most restrictive and unrealistic in this regard. Reluctance to use nonlinear models, however, would be reduced by careful attention to the residuals.

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