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SOME ASPECTS OF THE METHODOLOGY OF POPULATION FORECASTS FOR GEOGRAPHIC SUBDIVISIONS OF COUNTRIES

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Introduction.- Accurate forecasts of the population of the major geographic subdivisions of a country or of a specific geographic area, e.g., a state or city, are a continuing and pressing need on the part of many organizations in a nation. At the local level practical needs must be met in connection with planning future requirements for water, transportation and roads, schools, hospitals, etc. For this purpose, city planners want long-term forecasts.1 Federal and state planning agencies similarly have need for forecasts of the major geographic segments of the nation or state in connection with short-term and long-range planning for water and power development, roads, conservation of resources, etc. Population forecasts for small geographic areas are also needed by sales forecasters, and by business firms planning the future size of their industrial plant.

Most consumers of forecasts for geographic areas are concerned with quite practical problems and seek the most realistic figures possible. The numerous qualifications that go with "projections" are considered inconvenient. It is for that reason that I am concerned in this paper principally with "forecasts" rather than with "projections," although the basic method of forecasting often is the projection of past trends in some manner or other.

The problem of local forecasts differs from national forecasts essentially in the different role of migration. Because of the ease with which persons may move about within a nation, the volume of internal movement

may be considerable, as compared with movement across national borders. Migration is a much more variable element in population change than births and deaths, and hence is less capable of accurate prediction. For a given area, at times it may transcend natural increase in size; at other times, it may be negligible. Hence, also, local forecasts are ordinarily subject to greater error than national forecasts. In view of the significant role of migration, careful attention must be given to this component in the preparation of local forecasts. Failure to take account of it, either explicitly or implicitly, may lead to totally unrealistic results or, at best, a projection model assuming zero net migration.

Outline of methods.- The methods now employed of making forecasts for geographic subdivisions of a nation show an impressive but bewildering variety, with little standardization or uniformity. Unlike the situation at the national level, no single generally accepted method has as yet evolved. In view of the wide variety of local situations represented and the differences in kinds of data available, the use of several methods would be expected. Unfortunately, however, the process of "natural selection" has not proceeded far enough to eliminate the less useful or valid methods, and to narrow the list down to a promising few. This may be slow in coming, if it ever will, in view of the number of lay practitioners in the field, the complexity of some of the methods and the special data required for them, the limited experience with several of the methods, the limited information regarding the relative accuracy of the various methods, etc.

We can, for convenience in presentation, classify the methods of making local forecasts into three broad groups: (1) mathematical methods, which make use solely of the past trend of total population in the area; (2) component methods, which make separate direct allowances for the three main components of population change, births, deaths, and migration; and (3) a miscellaneous

group of methods which make use of symptomatic series of data or independent data for past or future dates, to estimate the future total population without intermediate estimation of components.

The mathematical curves most frequently used to project the population are the arithmetic, the geometric, and the logistic, but there are numerous other possibilities. All of these may be applied in several ways; e.g., the arithmetic curve may be based on the last two observations, two selected observations, least squares. The mathematical methods have the advantage of simplicity and of requiring relatively few data. They also have a modicum of logic for use over short periods of time since a rather high correlation exists between changes in successive periods. Since the logistic conforms more closely than the others to a pattern of change characteristic of many populations over the long run and avoids the assumptions of endless increase or negative populations, it is more appropriate than the others as a long-range forecasting method. These methods can provide forecasts of the total population only, however, and do not allow for anticipated deviations from past trends.

The component methods also have a large number of variations. We can first distinguish those forms which involve projections of total births, deaths, and migration from those which work with age cohorts and projected survival rates. Births and deaths may be projected by comparing local with national crude birth and death rates (or age-specific birth and death rates in the cohort-component method) for past and current dates, and applying the last observed ratio, or an extrapolated ratio, to national projections of fertility and mortality already available. Lacking national projections, birth and death rates may be extrapolated directly, possibly by means of mathematical curves. As for migration, zero net migration may be assumed, or the migration allowance may be a constant arbitrary amount or rate in

round numbers (e.g., 10,000 per year, one percent per year); a constant amount or rate equal to the volume of net migration during the preceding intercensal period; or changing amounts or rates representing extrapolations of the amounts or rates of preceding decades. For example, the first of the two comprehensive sets of state population projections which have been published by the U.S. Government employed two of the variations of the cohort-component method mentioned. These projections, which were prepared by Thompson and Whelpton of the Scripps Foundation and published by the National Resources Planning Board in 1934, extended to 1960. 2 One series in the report made no allowance for net migration; the second included a constant decennial allowance equal to the volume of net migration estimated for the 1920-1930 decade. A more analytic approach bases the allowance for migration on an analysis of economic prospects for the area, taking into account local and national prospects in major industry and occupation groups, employment, production, income, etc. For this purpose, general qualitative analysis, correlation, or ratio techniques may be used. (More detailed consideration will be given to this approach below.)

The component methods, in general, have the advantage of being logical; of making it possible to take account of anticipated changes in specific components and of the available knowledge regarding the determinants and correlates of population change; and of providing a great deal of useful "information" in addition to the forecasts of total population. These advantages appear to be especially true for the cohort approach.

A wide range of methods makes limited use of independent data for past or future dates. In the analogy method the average growth trend of other similar areas of like size in the past is borrowed by the area under study. In view of the demonstrably wide variation in growth rates of cities of a given size, this method is illogical and ill-founded. In the apportionment method future growth in a nation is prorated among the component areas in

accordance with their relative growth during a previous period (except that areas which previously lost population are assumed to remain unchanged). This method requires acceptable forecasts of national population. It is relatively simple to apply, but makes the doubtful assumption that the future pattern of growth will be exactly the same as in the past period.

A commonly used method in the United States is the so-called ratio method. It essentially involves projecting the proportion which a given area constitutes of some larger area and applying this projected proportion to the total for the larger area. This method assumed the availability of satisfactory forecasts for the broader area, usually the nation as a whole. In the long form of the ratio method, one unit is related to the next larger unit, which is related to the next larger unit, etc. In the short form, intermediate areas are omitted. The ways of projecting the ratios are as varied as the ways of projecting any time series. The U.S. Census Bureau used the following variation of the ratio method in preparing the set of state projections for 1955 and 1960 which it published in 1952. 3 First, the ratios of the divisions to the nation and of the states to the divisions were computed for each census from 1920 to 1950. Next, the initial future annual rates of change in the ratios were established on the basis of the level of the rates of change between 1920 and 1950 and the consistency of the direction of change in the ratios in this period. It was then assumed that the annual rates of change in the ratios would decrease linearly to zero in fifty years, i.e., the ratios would become constant. The projected divisional ratios were then applied to projections of the national population to obtain divisional projections, and the projected state ratios were applied to the latter to obtain state projections. The ratio method is fairly mechanical and depends heavily on the regularity of past trends. It is logical, however, in that it recognizes the interdependence of population

changes in the parts of a nation. The method is simple to apply, can be extended easily to additional component areas and age-sex estimates, 4 and permits rapid revision of results as revised national forecasts become available.

"Holding capacity" is sometimes used as a basis for forecasting the population of a city. This involves consideration of zoning regulations, vacant dwelling units, vacant land, topography, trends in household size, etc. This method is best adapted to built-up cities which cannot expand their areas; experience here shows a very wide range of possible error. Schmitt has recently suggested a regression relating change in the future population of the city to the present population density of the city and the future change in the population of the state. 5 This method is based on a reasonable selection of "determinants", but it assumes that highly accurate state forecasts are available -- a generally untenable assumption.

Forecasts based on economic analysis.-- We pass over a miscellaneous variety of infrequently used methods involving a wide variety of materials and techniques to come, finally, to several methods involving extrapolation of past trends in various kinds of symptomatic economic data and conversion of the projected economic series into population forecasts. Simplest of these is the correlation of total population with an economic variable and the solution of the regression equation for a given forecast of the variable. Often, directly or indirectly, a forecast is made of the area's future employment or labor force; this forecast is then converted into population by a ratio method. General qualitative analysis, correlation, or ratio techniques are used to arrive at the forecast of employment. It may be based on an intensive analysis of past trends in a major industry in the area or in each industrial branch, relative to national trends, and on projection of these trends to a future date on the basis of national forecasts for the industry

or industrial groups. The basic analysis may be in terms of employment in primary industry, which is then expanded to total employment by applying an assumed future ratio of secondary to primary employment.

Another procedure for forecasting employment in an area is to establish, first, on the basis of past trends, how the area may be expected to share in estimated future national production and then to convert this local production into numbers of workers on the basis of estimated future levels of output per worker. 6 This method requires satisfactory forecasts of national production and productivity and satisfactory past data on these items for the areas included in the analysis. One or more of the income concepts are usually used to measure national production. The frequent lack of the necessary data on local income or production now limits the usefulness of this method. A third method of forecasting employment, called the "input-output technique," is still in the experimental stages but is mentioned here because of its future possibilities. It derives employment data by industry (1) by applying empirically developed inter-regional-interindustry coefficients showing the flow of commodities, to the appropriate estimates of prospective demand for the output of each industry and (2) by dividing the estimated future output for each industry by the estimated output per worker for each industry. 6

The writer believes that the methods which attempt to assess the economic prospects of an area represent the most logical and promising approach to the problem of forecasting local populations. It is well known that the principal determinant of the volume and direction of migration in a country is the relative economic opportunity afforded by the various regions of the country. The making of assumptions regarding migration to an area within the country should, therefore, be facilitated by the careful assessment of the economic possibilities of the area.

It is believed that a general economic analysis of an area should form part of a comprehensive job of making population forecasts for the area.7 Since the area's economy is intimately related to the economy of the surrounding area, and in turn to the economy of the country, attention should be given to trends in these larger areas and to the relation of local to national trends. National past and prospective trends in income, production, and employment should be taken into account. Consideration should be given to such factors as the relative per capita income in the area and the nation, the relative wage scales or average annual earnings of workers in major lines of activity the relative opportunities for steady year-round employment, etc. A detailed guide for making such an economic analysis in connection with making population forecasts is provided in a recent publication of the U.S. Department of Commerce.8

Further refinement can be introduced into a methodology involving economic analysis by including it as part of a cohort-component method. Possible steps in this intensive procedure are: (1) Compute projections by age and sex, by the cohort-component method assuming no net migration; (2) determine future employment, by age and sex, by one or more of the methods mentioned above; (3) convert employment into labor force, by assumed unemployment rates; (4) convert labor force into population or working age, by age and sex, by use of assumed age-sex-specific worker rates; (5) by comparing the population of working age in (4) with the expected population in (1), derive forecasts of net migrants of working age; and, finally, (6) estimate the number of persons outside the working ages who accompanied the working-age migrants or who were born to them since their arrival. To carry out this procedure or any of the more analytic cohort procedures effectively, further development of basic data and

methods in migration and economic analysis is necessary; e.g., we need to know more about the causes of migration, demographic and economic characteristics of migrants, social and economic correlates of migration, assessment of national and local economic prospects, etc. Admittedly, the method outlined is quite time-consuming, but it promises to provide a large body of useful population and economic material for the area. Unfortunately, there is no guarantee that it will produce materially more accurate forecasts than the simpler methods. We turn now to the question of accuracy.

Accuracy of forecasts. - Relatively few systematic tests of the relative accuracy of various methods have been conducted so far. For the most part, forecasters have been selecting a method on the basis of practical considerations or a priori judgements regarding the relative accuracy of the methods with which they were familiar, rather than on the basis of the results of tests of the accuracy of various methods.

There are two basic ways of designing a test of accuracy. One is to compare actual forecasts made by various estimators in earlier years with later census counts. The second is to develop "forecasts" for past census dates using data only from prior census periods and to compare these hypothetical forecasts with the census counts. Each of these methods has its advantages and disadvantages. The leading argument in favor of the first type of test is that it recognizes that most researchers, in practice, carefully consider alternative methods for each area before making a final selection, and adapt the method to the situation in each area, avoiding the use of a uniform method for all areas.[9] Moreover, all methods have such infinite variations in practice, as molded by the judgement of the researcher, that any simplified version of it employed for testing purposes would not do justice to it. Further, the tester is quite likely to make the mistake of using current information which would not have been available

to him under actual forecast conditions. On the other hand, this design has the important theoretical weakness of using forecasts which vary at once with respect to the identity of the area estimated, the specific methods used, the length of the forecast period, and the calendar period represented.[10] In addition, the numerous variations of a particular method employed may render difficult or impossible the very important classification in terms of type of method. Other practical difficulties include the failure of the forecaster to describe the method adequately; to specify the actual base date of the forecasts, rendering difficult or impossible the important allowance for the length of the forecast period; to specify or compute a best estimate when several projections are developed for a single date; to present forecasts for the nearer dates, obviating comparison with the next census; and to define the area estimated precisely.

Some tests of both types have been conducted in the United States. A review of the more important tests will suggest some of the problems and results of the tests. The early tests include those of Houser in 1928 [11] and Chamberlain and Crawford in 1932.[12] These two tests made use of forecasts already available rather than "forecasts" of the researcher's own making. Houser made 405 comparisons of forecasts derived generally by mathematical or graphic methods given in 59 reports of engineers issued between 1872 and 1922. The average error (disregarding signs) increased progressively from 6 percent for the 5-year forecasts to 34 percent for the 30-year forecasts. The range of error for the 5-year forecasts was from 25 percent too low to 30 percent too high! Divergences as high as 90 percent appeared in 35 years. This study failed to take adequate account of variations in method. Chamberlain and Crawford compared forecasts for 43 cities for 1930, classified into 4 groups according to method, with 1930 census figures. The average error ranged from 12 percent for the

10 cities which used a component method to 39 percent for the 8 cities which used a correlation method, with an average error of 17 percent for all methods combined. This study failed to take into account variations in the length of the forecast period.

A more systematic test was conducted in 1952 at the Bureau of the Census by White.[13] The relative accuracy of various methods of forecasting state population was measured by comparing hypothetical forecasts for 1940 and 1950, based on current data through 1930, with census figures for those dates. The methods tested included the cohort-survival method (with and without migration),[2] several variations of the ratio method, and three "mathematical" methods (arithmetic and geometric extrapolation, and the apportionment method). No one method was found to be clearly superior, but the cohort-survival method (adjusted for migration), the apportionment method, and one variation of the ratio method (Ratio III) make the generally best showing, on the basis of the average percent error and the proportion of errors of 10 percent or more. A consistently poor showing is made by the variation of the ratio method in which a 60-year trend in the ratio is extrapolated (Ratio I), as compared with the use of a 10, 20, or 30-year trend (Ratio III) or holding the 1930 ratio constant (Ratio II). The average error for all methods combined in 1940 was 7 percent, but for the cohort method (with migration), it was only 5 percent. Even here, however, 12 percent of the errors exceeded 10 percent. Considerably larger errors occur with the 20-year projection period than with the 10-year period. For the 20-year period, the average error for all methods combined was 15 percent and 54 percent of the errors exceeded 10 percent. About 50 percent of the errors exceeded 10 percent for the cohort-survival method and ratio method II, taken separately. Larger errors are also related to smaller base populations and to higher average migration rates for states.

Similar tests for 20 large cities and their standard metropolitan areas were conducted in 1951 and 1953 by Schmitt.[14;15] Forecasts were computed for 1940 and 1950 on the basis of trends from 1890 to 1930 and compared with census figures in 1940 and 1950. The methods tested were the analogy method, arithmetic (least squares), geometric (least squares), logistic, and short and long forms of the ratio method (least squares or logistic). The logistic curve, arithmetic extrapolation, and the two forms of the ratio method produced almost equally accurate results, on the average; they were much more accurate than either geometric projection or the analogy method. The forms of the ratio method were about equally accurate. The logistic and the ratio methods had average errors of 9 percent each for the 10-year projection period, for cities, whereas the geometric method had an average error of 33 percent. Twenty-year forecasts were less accurate than 10-year forecasts, but not excessively so in all methods. For the 20-year period, for cities, the errors of the logistic and ratio methods were 11 percent and 15-16 percent, respectively. Metropolitan area forecasts differed little from forecasts for central cities in degree of accuracy. In a special test, the ratio method indicated a generally greater accuracy for slowly-growing cities, but accuracy was not significantly related to size of city at the base date.

Schmitt also conducted an accuracy test for his regression employing population density in a city and future change in state population to forecast city population.[5] Though his use of actual state figures for the future date must have reduced his error, the test showed several very extreme errors (3 over 24 percent) in a 10-year period. The method was least accurate for rapidly growing cities but absolute size of city was unimportant.

In 1952 the writer compared 99 actual forecasts published between 1930 and mid-year 1952 with census figures for 1940 and 1950.[16] The average error was 8.4 percent and more than one quarter of the errors were 10 percent or more. These are considered high figures in view of the fact that the forecast period (determined from the publication date) was under 10 years in all but a few instances and quite commonly under 5 years. The average error was found to be 7.6 percent for forecasts of less than 5 years and 9.6 percent for forecasts of 5 or more years. The average error ranged from 5.7 percent for the ratio method and 5.9 percent for the cohort-component method to 10.3 percent for the simpler component method. The practical difficulties experienced by the writer in conducting this test confirmed his belief that, at the local level, testing with hypothetical forecasts gives more useful results.

Finally, the writer examined the differences between (1) ratio projections for states for July 1, 1953, based on July 1950 postcensal estimates and consistent with the U.S. Census Bureau projections for 1955, and (2) current state estimates for July 1, 1953. Presumably the current estimates are accurate enough to reveal any large errors in the projections. Already, for this 3-year period, 5 states had deviations exceeding 5 percent and 2 states had deviations over 10 percent; these two were relatively small states with very high growth rates. At the divisional level, the maximum deviation was only 2.7 percent, however.

The results of these studies must be considered in the light of the accuracy needed. Most consumers of forecasts would assert that a rough figure is better than none at all. Figures with even a wide range of error in the long-run can be useful in general planning, since planning standards are quite variable in practice; this is subject to the proviso that the figures are revised periodically as the need appears.[17] On the

other hand, large errors in the short-run can be damaging. The test results indicate that, with the methods tested, it is not possible to forecast the population of small geographic areas accurately, particularly for distant dates. The available test evidence does not point clearly to the use of a particular method as superior; there is no proved method of making local forecasts. From the point of view of accuracy, the simpler methods appear to be just as accurate as the more complex ones; hence, a simple method may justifiably be used where time, resources, and data are limited. Average errors are not always disturbingly large for short-term forecasts, but extremely large errors may appear in particular cases from the very start with any of the methods tested. The tests are consistent in showing an increase in the error with an increase in the length of the forecast period; 20-year forecasts generally have large average errors and a sizeable proportion of errors exceeding 10 percent. This finding tends to refute the claim sometimes made that forecasts may be satisfactory guides in the long run, even though they may be in great error in the short run. The indications regarding the relation of size of area to accuracy are not consistent, although a direct relation would logically be expected to hold, particularly so far as the extreme size categories are concerned. Until the evidence is more complete, a priori logical considerations suggest proceeding as if a direct relationship exists, at least in terms of gross size differences. Finally, accuracy seems to be reduced when growth rates are high.

It should be apparent that we do not have adequate information on the relative accuracy of present methods. Because the results obtained in validity studies are unique to the calendar period selected for the test, many more tests are needed covering forecast periods having widely

different economic characteristics and growth trends. The results of the few tests conducted so far can only be regarded as suggestive, not conclusive. Validity studies are needed also to test other methods not yet covered by such tests, particularly the more logically promising methods, e.g., those using economic indices. More crucial, perhaps, is the need for more research in methodology. Work in this area is in hardly more than a primitive state. Only a mere beginning has been made in the use of analytic techniques.

Outlook . - The outlook for improving the accuracy of forecasts is only mildly favorable. The degree of accuracy achieved for national forecasts cannot be expected for local areas. Forecasts of fertility are even more likely to go wrong for local areas than for a country as a whole, and success in prediction has not been outstanding in the latter domain. So far as prediction of net migration is concerned, only modest success can be hoped for. Regularity in internal migration trends may be rather limited. Shryock's recent analysis of interstate migration trends in the United States from 1910 to 1952 (9 migration periods) makes it appear that the pattern of interstate migration has been only moderately persistent in the United States, only one-third of the variation in one period being "explained" by the variation in the other periods; nor do the coefficients of correlation relating the volume of net migration in each period to every other period give any indication of a trend in the pattern of interstate migration.[18] The future economic possibilities of a local area can be only roughly surmised. This is partly because our ability to predict national economic conditions is quite limited. One careful study indicates that forecasting of economic changes at the national level, particularly of major economic turns, even by experts, does not attain a very high degree of success.[19] Industry is

now less tied down than formerly by specific locational requirements. Special factors may change past trends of industrial and population movements e.g., fear of atomic attack may lead to a dispersal of industry and hence of population, and technical progress, such as the development of new sources of power and of ways of transmitting it long distances, may open up new possibilities for industry and its location. Finally, we do not know just how the volume and pattern of interstate migration in the United States are related to economic conditions, both with respect to their level and direction of change.

On the more favorable size, considerable progress has been made in the measurement of current postcensal migration and hence of current postcensal populations; in the measurement of national economic conditions and their variations from area to area; and in the methods of assessing economic prospects for local areas. Intensive research is proceeding on the relation of economic development in the United States to the volume and pattern of internal migration.[20] Even though past patterns of interstate migration in the United States are not perfectly correlated, moderately useful generalizations could probably be made about the future pattern of net interstate migration in the short run. The chances of success in population prediction for a local area are enhanced by the fact that the forecast itself plays a part in making itself realized. The building of community facilities in expectation of a given population size tends to attract the population to use them. Moreover, in the case of "young" cities, the city planner can plan, through zoning, the type and intensity of future land use and so partly control the size of the future population. Frequent revision of forecasts will assure that they are reasonably consistent with the latest current population estimates and data, and increase the likelihood of accuracy, particularly in the short-run.

Although the writer is basically pessimistic about the possibilities of developing a method that does not, from time to time, give extreme errors, even over very short periods, he is reasonably optimistic about the possibilities of developing a method or methods which will give satisfactorily low average errors over a few decades and which will also be of considerable use as analytic tools. In any case, it is certainly reasonable to hope that, in time, evolving demographic research will develop more specific guides for forecasting the population of geographic sub-divisions of countries than now exist.

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