# PROBLEMS OF TREND DETERMINATION DURING A TRANSITION IN FERTILITY

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A CONTROVERSIAL component of recent population literature is the theory of the demographic transition, or, as it is sometimes called, the vital revolution. This loosely-woven set of propositions about the nature, causes, and consequences of long run decline in mortality and fertility, which received its major impetus from the work of the Princeton school of demographers[2] was acclaimed by Rupert Vance, in his presidential address to the Population Association of America, in 1952,[3] as the best opportunity for theory in a profession rife with empiricism. In contrast with this hope are the assertions of demographers working on underdeveloped areas that the transition theory is special to the West.[4] Even this limitation on generality is not stringent enough to suit some, and in particular Joseph S. Davis, who asserts that the United States and the British Dominions require a theory of their own, on the presumption that their fertility is not now declining.[5]

One contribution that a methodologist may make to the construction or demolition of the transition theory is in a sense a semantic one: to establish operational definitions of the vocabulary being used and determine relationships between component parts of the structure of ideas, so that the protagonist and antagonist may at least converse with each other. The present paper is intended to discuss some matters pertinent to the central concept in the vital revolution—the trend of fertil-

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[2] *See,* for example, Notestein, F. W.: Population—The Long View, pp. 36–57 in Schultz, Theodore W. (ed.), FOOD FOR THE WORLD, University of Chicago Press, 1945.

[3] Vance, R. B.: Is Theory For Demographers? *Social Forces,* 31, 1, October, 1952, pp. 9–13.

[4] *See,* for example, the papers by Irene B. Taeuber and Kingsley Davis in THE INTERRELATIONS OF DEMOGRAPHIC, ECONOMIC, AND SOCIAL PROBLEMS IN SELECTED UNDERDEVELOPED AREAS, New York, Milbank Memorial Fund, 1954, pp. 9–31 and 66–89.

[5] Davis, J. S.: Population and Resources. *Journal of the American Statistical Association* 45, 251, September, 1950, pp. 346–349.

ity. There are many definitions of fertility, depending on the nature of the hypothesis being examined or, more frequently, the type of data available. Some of these are discussed here in terms of setting forth relationships between the time series of the different measures and thus indicating the extent to which a proposition about changing patterns of childbearing, with one type of measure in mind, needs to be amended if another definition is utilized. The establishment of a bridge between various definitions of fertility has been a major achievement of recent demography. This paper may be viewed as an attempt to apply some aspects of this achievement to an important segment of demographic theorizing. That fertility declined in the West during the past century is a fact on any measurement basis. But it now seems desirable to attempt to introduce a greater level of precision into the observations, to measure the changing rate of decline, the length of the interval between falling mortality and falling fertility—in short to move from a verbal to a quantitative level of statement.

The measure most frequently encountered in publications dealing with the vital revolution (aside from the generic term 'fertility') is the birth rate.[6] The frequency of occurrence of this term is almost certainly not evidence of a choice on analytic grounds but rather a reflection of the plain fact that, for most countries during the early phases of the small-family movement, this is the only measure which can be calculated. Furthermore the term "birth rate" is apparently used as a general synonym for fertility in writings for a non-technical audience. It should, however, be added in defense of this much-maligned measure that it is an unequivocal measure of the consequences of the various forces which it is the purpose of refinement to unravel.

A second meaning of fertility is that given by some index of the age-specific birth rates observed during a particular period.

[6] For example, Vance's chart of the course of the vital revolution in England portrays changes in the crude birth and death rates. Vance, R. B.: The Demographic Gap. Pp. 9–17 in APPROACHES TO PROBLEMS OF HIGH FERTILITY IN AGRARIAN SOCIETIES. New York, Milbank Memorial Fund, 1952.

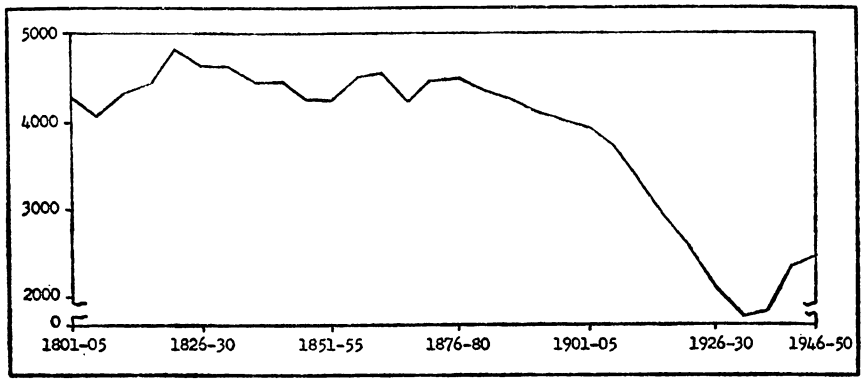
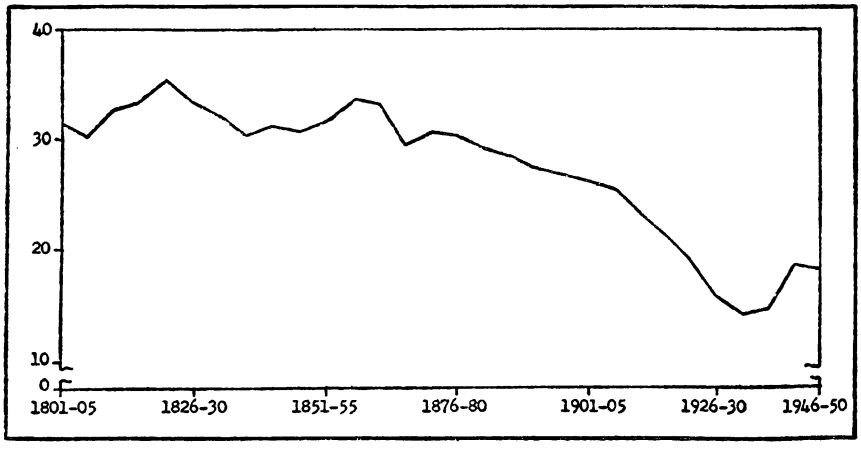



Fig. 1. Crude birth rate (per thousand), Sweden, 1801–1950.

Although the most common of these indices is the gross reproduction rate, it has seemed preferable here to use the total fertility rate, which is virtually the same except that it summarizes age-specific rates for all births rather than just for female births. This preference is based on a desire to avoid the implication of replacement or of connection with the stable population model (which, because it is a static model, is peculiarly inappropriate to the study of demographic change.) In Figures 1 and 2, the Swedish crude birth rate and total fertility rate are plotted for five-year periods during 1801–1950. Where these measures are distinguished, in articles discussing long run move-

Fig. 2. Period total fertility rate (per thousand), Sweden, 1801–1950. [See Appendix B.]



ments in reproductivity, the implication is that the crude rate is inferior to the other as a measure of fundamental fertility, because of the influence of a changing age distribution.[7] The thesis, a classic one in demographic discussion, is that, under a regime of declining mortality followed by declining fertility, the age distribution evolves in such a way as to inflate temporarily the age groups responsible for childbearing. This was perhaps the most striking feature of the famous 1925 article by Dublin and Lotka.[8] The picture conveyed in such discussions of the subject is of a transitory phase in the vital revolution in which the crude birth rate is hoisted to spurious heights because of a wave of growth passing upward through the age structure, much like a boa constrictor swallowing a pig. Such contamination of the trend is eradicated by performing the operation of age-specification and achieving a total fertility rate.

In the writer's opinion the influence of the long run evolution of the age distribution, during the course of a typical demographic transition, on the trend of fertility as depicted in a time series of crude birth rates would seem to be fairly modest. Figure 3 contains a graph of the relationship between movements of the crude birth rate and movements of the total fertility rate in Sweden.[9] It is evident from this graph that significant distortions of fertility behavior can occur if reliance is placed on the crude birth rate as a measure, but in the present instance at least they are attributable in the main to transitory factors. The early trough and peak in Figure 3 was caused by a sharp

[7] For instance, in Notestein, F. W.: The Population of the World in the Year 2000. *Journal of the American Statistical Association* 45, 251, September, 1950, pp. 335–349.

[8] Dublin, L. I., and Lotka, A. J.: On the True Rate of Natural Increase. *Journal of the American Statistical Association*, 20, 151, September, 1925, pp. 305–339.

[9] Since the crude birth rate and the total fertility rate are measures with different dimensions, it was considered advisable in comparing their time series to express each series in terms proportional to the mean value for the whole series and then to divide the consequent relative crude birth rate by the consequent relative total fertility rate for each time period. This practice seems justifiable because of the high degree of similarity of the curves as shown in Figures 1 and 2. The coefficient of variation of the crude birth rate series is 22.6 per cent and of the total fertility rate series is 23.9 per cent.

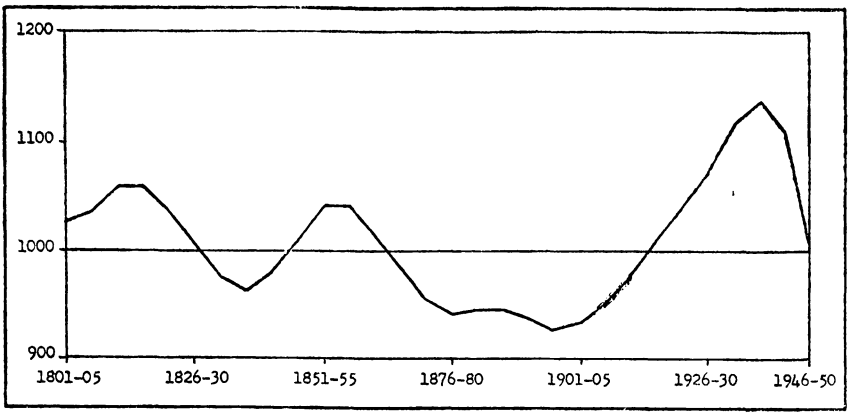



Fig. 3. Ratio of relative crude birth rate to relative total fertility rate (per thousand), Sweden, 1801–1950. (See footnote 9 in the text.)

drop in mortality, particularly among children, which released a wave of growth depressing the crude birth rate until the larger cohorts advanced into their reproductive prime of life. The second and more extended trough was a function of the very heavy migration of the late nineteenth century, which was highly selective of young women. Even more telling in its effect on the relationship between the crude birth rate and the total fertility rate is a fluctuation in fertility, because its influence is focused on one age alone, viz., zero. Thus the great depression is reflected in the recent sharp peak in Figure 3. In addition to these familiar factors, there is another which, although modest in its empirical significance, has been unjustly ignored in the literature. The section of the age distribution which affects the birth rate directly is that which lies within the reproductive age span. Now the relative importance for childbearing of various age groups may and does change considerably, as will be noted presently. A significant component of the transformation of reproductive patterns in the West has been a shift of the locus of fertility toward a lower and lower age. Since the younger age groups are typically larger than the older, this shift induces a less rapid rate of decline in the crude birth rate than in the total fertility rate.[10]

[10] For a statement of this in symbolic form, *see* Appendix A.

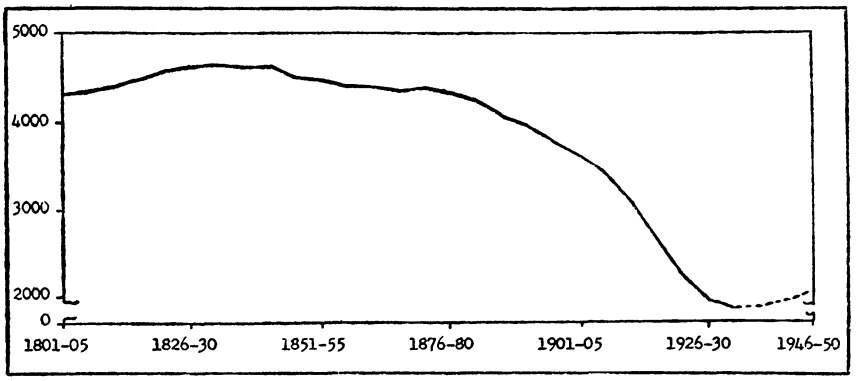



Fig. 4. Dated cohort fertility rate (per thousand), Sweden, 1801–1950. [For sources and dating procedure, see Appendix B.]

The total fertility rate discussed up to this point is computed by summing the age-specific birth rates of the female population during a given time period. If a table of such rates is prepared for a population through time, with the rows representing ages and the columns time periods, then the sum of any column is the total fertility rate for the period concerned. The convincing claim has been put forward in numerous recent publications [11] that it is more meaningful for most analytical purposes to consider not the synthetic aggregate of the behavior of women of different ages in a single period, but rather the complete history of childbearing of women born at the same time, birth records being cumulated throughout their lives, and age increasing *pari passu* with time. This latter concept would be represented in the aforementioned table by the sum of a diagonal of birth rates, called the cohort total fertility rate. Thus there are two time series of total fertility rates available, one cohort and one period. The latter has been presented in Figure 2 above; the former is shown in Figure 4. The two series are approximately alike, except for the greater short run variability of the period than of the cohort series. Similarities are, of course, to be expected, since both series summarize the same table of fertility as a function of age and time, but there are

[11] For a bibliography and discussion, *see* Stolnitz, G. J. and Ryder, N. B.: Recent Discussion of the Net Reproduction Rate. *Population Index* 15, 2, April, 1949, pp. 114–128.

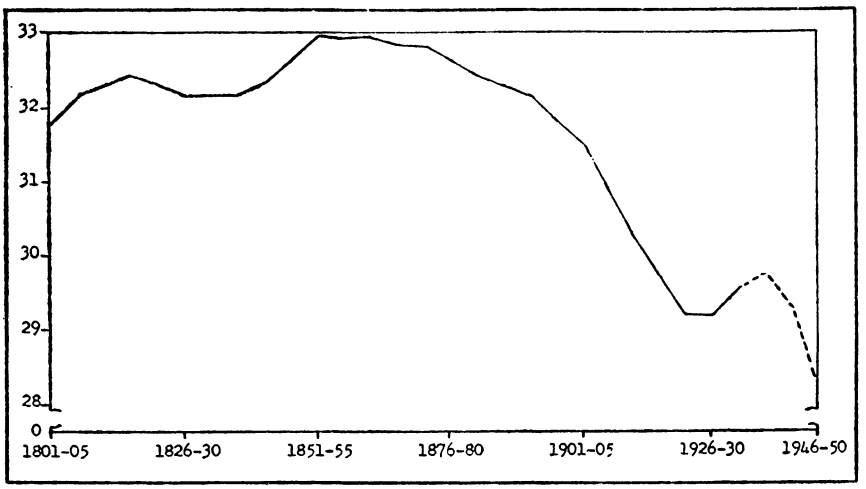



Fig. 5. Dated cohort mean age of fertility, Sweden, 1801–1950. [For sources and dating procedure, see Appendix B.]

points of critical difference at the refined level of statement required for progress in knowledge of the vital revolution. (*Vide infra.*)

It is now well-recognized that period indices of age-specific fertility are highly responsive to year-to-year changes in the socio-economic climate, without any necessary inference that such movements reflect changes in the total childbearing of the constituent cohorts in the population. It is also generally agreed that the mechanism of this fluctuation, the proximate source in an arithmetical sense, is the variations which occur in the timing of childbearing, either because of marriage postponement, or because of postponement of births within marriage.[12] It is not appreciated however that changes in the timing of childbearing create a divergence of the trend of period fertility from that for cohorts not merely when the changes are temporary and violent, such as in a context of war or depression, but also when they have a gradual long run character. In Figure 5 a simple measure of the timing of fertility is plotted. This measure is computed for a cohort by multiplying each age by

[12] *See* Whelpton, Pascal K.: COHORT FERTILITY, Princeton University Press, 1954, Chapter 6 *et passim.*

its respective fertility rate, summing the products and dividing the sum by the total fertility rate. In other words it is the mean of the fertility-age function.

As seen in the graph, major changes in this measure have accompanied the transition of fertility from a high to a low level. Since the middle of the nineteenth century the mean age of fertility has followed a strong downward course in Sweden, mostly because the birth rate has fallen more sharply in the older than in the younger childbearing ages, but partly because the mean age at marriage has been declining. Now when successive cohorts bear children in approximately the same time pattern, their fertilities overlap, so to speak, so that the amount of fertility in any one period corresponds with the average amount of fertility for the constituent cohorts. But if the mean age of fertility is falling, the births of successive cohorts are bunched more closely together—there is an augmentation of the normal overlap—and the fertility of any one period tends to exceed that of the cohorts represented therein. The period receives a spurious surplus of births. An example of the converse proposition is a postponement situation, such as occurs during a depression. Postponement may be rephrased as a rise in the average age at which childbearing occurs—a diminution of 'normal' overlap—leading to a spurious deficit of births in the period concerned.[13]

To permit closer inspection of the ways in which the time series of period fertility differs from that for cohort fertility the ratio of the period total fertility rate to the cohort total fertility rate has been calculated and the results are presented in Figure 6, labelled the "Index of Timing Distortion." It is clear from this graph that, contrary to what might be the superficial

[13] These matters have been discussed at length in the writer's unpublished Ph.D. dissertation, "The Cohort Approach. Essays in the Measurement of Temporal Variations in Demographic Behavior," Chapter IV, Princeton, 1951. A parallel and independent treatment dealing principally with nuptiality and emphasizing short run variations in timing is contained in Hajnal, John: Births, Marriages and Reproductivity, England and Wales, 1938–47, Section D, pp. 385–403. REPORTS AND SELECTED PAPERS OF THE STATISTICS COMMITTEE, PAPERS OF THE ROYAL COMMISSION ON POPULATION, VOLUME II. London, His Majesty's Stationery Office, 1950.

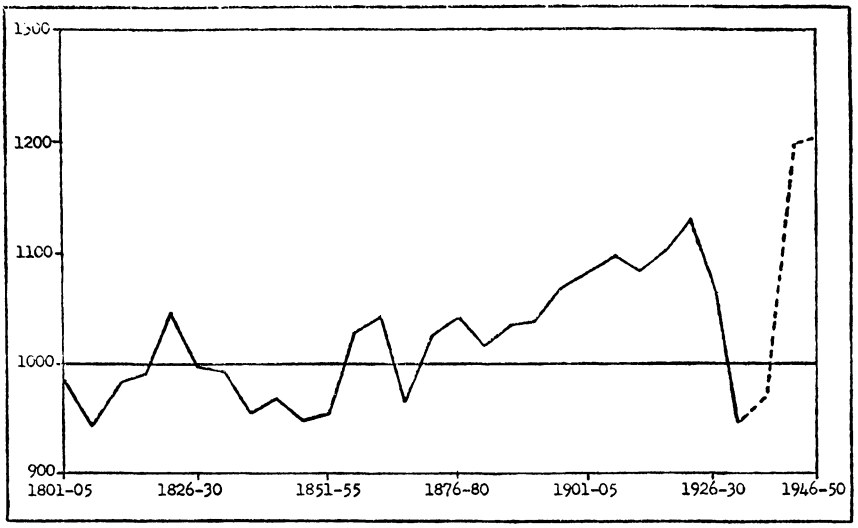
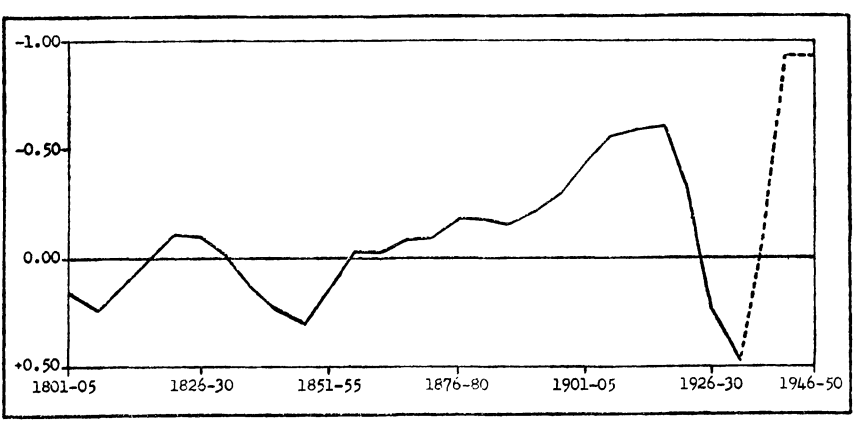



Fig. 6. Index of timing distortion (per thousand), Sweden, 1801–1950. Ratio of period total fertility rate (Fig. 2) to dated cohort total fertility rate (Fig. 4).

impression concerning the relationship of these two measures, the period rate does not merely fluctuate about the cohort rate. On the contrary it has shown systematic long run divergence from the cohort series—and at times of considerable proportions. Over a sixty-year span, period fertility in Sweden was higher than that for cohorts, and the discrepancy mounted to 13 per cent. The great depression reversed the direction of

Fig. 7. Change in cohort mean age of fertility (plotted inversely), Sweden, 1801–1950. [For dating procedure, see Appendix B.]



distortion temporarily, but during the 1940's period-type fertility was apparently about twenty per cent higher than its cohort counterpart.

Changes in the timing of fertility of successive cohorts have been responsible for the divergence of the period fertility series from that for cohorts. In Figure 7 are plotted (inversely) the changes in the mean age of fertility from cohort to cohort. The high degree of correspondence between changes in fertility timing, shown in this graph, and the distortion of cohort fertility by the period rate, shown in Figure 6, is immediately evident. On the basis of the above, it is considered important in any attempt to refine propositions concerning the vital revolution to pay careful attention to possible changes in the timing of cohort fertility, because of the direct way in which these changes, whether they are short run or long run, cause the various period-type measures of reproductive performance to distort underlying cohort behavior. As a specific corollary to this proposition, it seems likely that postwar fertility in the Western world has been spuriously high not only because of the recovery of postponed births, but also because of the gradual but persistent trend toward earlier childbearing. This defect of period-type measures is, furthermore, not removed by increasing the level of specificity of the rates, i.e., by computing birth rates which are specific for parity, for marital duration and so forth. So long as these indices consist of the aggregation of birth rates for a series of cohorts in a particular period, they bear the mark of any changes which may be occurring in the time pattern of fertility.[14]

There is, of course, plenty of scope for the refinement of measures of cohort behavior beyond the level of age-specificity. Probably the most common fertility referent in the analysis of reasons for decline is the concept of family size. This measure of fertility may be defined operationally as the ratio of the number of legitimate births to a cohort of women, divided by the

[14] *See* Ryder, N. B.: The Comparative Relevance of Cohort Aggregation and of Increased Specificity in the Determination of the Trend in Fertility. World Population Conference, Rome, Italy, September, 1954.

number of first marriages occurring prior to menopause. Alternatively the computation may be based on census records of children born to ever-married women who are now beyond the fecund ages. Either of these measures of cohort family size (which differ only to the extent that mortality or migration may be selective in respects relevant to childbearing) will in general yield a different time series, a different trend of fertility, from that depicted in a graph of cohort total fertility rates, and the divergence requires explicit consideration if the hypotheses being examined bear on the character of familial institutions. The reason for discrepancy in this case is, simply, the variations of nuptiality as a function of time. That marriage is a more dynamic variable than was thought previously has been amply documented in Hajnal's recent group of articles on the subject.[15] The materials assembled by the present writer in this connection have been presented elsewhere in an article which is, in a sense, a companion piece to the present one.[16]

The list of different fertility measures, each of relevance to some phase of the analysis of declining reproductivity, could easily be extended.[17] For present purposes it may suffice to note that the special characteristics of each measure tend to give it a unique time-pattern of change, which cannot necessarily be inferred from the time series of some other measure. Another problem, implicit in the above discussion, deserves however a short comment. It is clear that the theory of the demographic transition is couched in terms of a long run model and that the statements about changing patterns of childbearing refer to the trend in fertility rather than to whatever fluc-

[15] Hajnal, J.: Age at Marriage and Proportions Marrying. *Population Studies,* 7, 2, November, 1953, pp. 111–136, (among others).

[16] Ryder, N. B.: The Influence of Declining Mortality on Swedish Reproductivity. CURRENT RESEARCH IN HUMAN FERTILITY, Proceedings of the 1954 Annual Conference of the Milbank Memorial Fund. Milbank Memorial Fund, 1955, pp. 65–81.

[17] For example, probably the most pertinent measure for testing the influence on fertility of the increasing use and efficacy of contraception is the ratio of conceptions to exposed fecund ovulations. This ratio can vary through time quite differently from the fertility rates discussed above because failure to prevent conception confers a period of immunity, i.e., of pregnancy, whereas success in preventing conception implies exposure to the risk of conception at the time of the next ovulation.

tuations may be occurring. The test of the hypothesis of declining fertility in the United States, for example, requires prior agreement on the manner of identification of the trend, as well as on exactly which "fertility" is being examined. Although a large part of the apparent transitory variability in reproductive performance vanishes when cohort measures are utilized in preference to the conventional period indices, numerous problems remain unanswered in this area unless there is an arbitrary decision to define the trend as whatever successive cohorts do. For example, the tables of age-specific order-specific birth rates for native white female cohorts in the United States, assembled by Whelpton,[18] can be used to show that more births per woman will occur in some later cohorts than in some earlier ones in recent American history. Before this is signalled as a reversal of secular decline, there must be an assessment of the extent to which the cohorts which spent their most important reproductive years enduring the ravages of the depression incurred because of this a loss which could not be later recovered. In the second place, a part of the rise in cohort fertility which is occurring is attributable to an increase in the number of families, i.e., in the likelihood of marriage, as distinct from the number of children per family (which is the focus of study in the theory of declining fertility). Finally the rise which is occurring is for the most part a matter of decreases in the proportions of families with no child or one child, decreases which more than counterbalanced the continuing decline in families with larger numbers of children. The average family size for women with at least two children is clearly continuing its downward path. For example, the cohort of women born in 1906, which by January 1, 1953 had effectively completed its childbearing, spent many of its good reproductive years enduring the depression and arrived in the postwar period at too late an age to do much toward recouping its deficits. Nevertheless the women of this cohort in parities two and higher had at every age a higher average number of births than

[18] *Op. cit.*, Table A.

any of the following cohorts have achieved (at a comparable age) up to 1953.[19]

In short, the adoption of the cohort viewpoint is a necessary but not a sufficient condition for adequate interpretation of current fertility movements. Furthermore the user of cohort tables requires an excessive amount of discretion (not to mention patience) because if he were to compare the levels of fertility achieved by two cohorts whose experience was still incomplete, he would be in danger of recording quantity differentials which might be entirely attributable to the phenomenon on which attention has been focused above, viz., modifications in the timing of childbearing. The failures of the forecasters may in large part be attributed to the confusion of long run quantity variations with short run timing variations, partly because of a lack of distinction between period fertility and cohort fertility, and partly also because of the impatience which is a chronic feature of a policy-oriented science. At the same time, the critics of these forecasts[20] are open to the charge that they too have failed to distinguish between trend and fluctuation—and the meaning given to "fertility" is often restricted to the crude birth rate, if not the number of births. The forecasters looked at the 1920's and 1930's and saw major decline; the critics looked at the 1930's and 1940's and saw major expansion. The controversy has been somewhat reminiscent of the story about the blind men interpreting the elephant from different ends.

The need to be crystal-clear about what is being measured is more important now than ever before. Figure 8 contains the graph of the conventional gross reproduction rate for the United States, 1930–54. This measure of "intrinsic" fertility has been increasing now for twenty years. The only irregularities in this

[19] This calculation is made by computing the ratio of the cumulative birth rates of orders two, three, and higher to the cumulative birth rate of order two, as published in Tables A and G of Whelpton, *op. cit.*, and in the mimeographed supplement to Table G (Scripps Foundation, March, 1955), for the cohort of 1906 and for the experience of the various younger cohorts up to January 1, 1953.

[20] Especially Davis, Joseph S.: The Population Upsurge in the United States. Food Research Institute, Stanford, 1949.

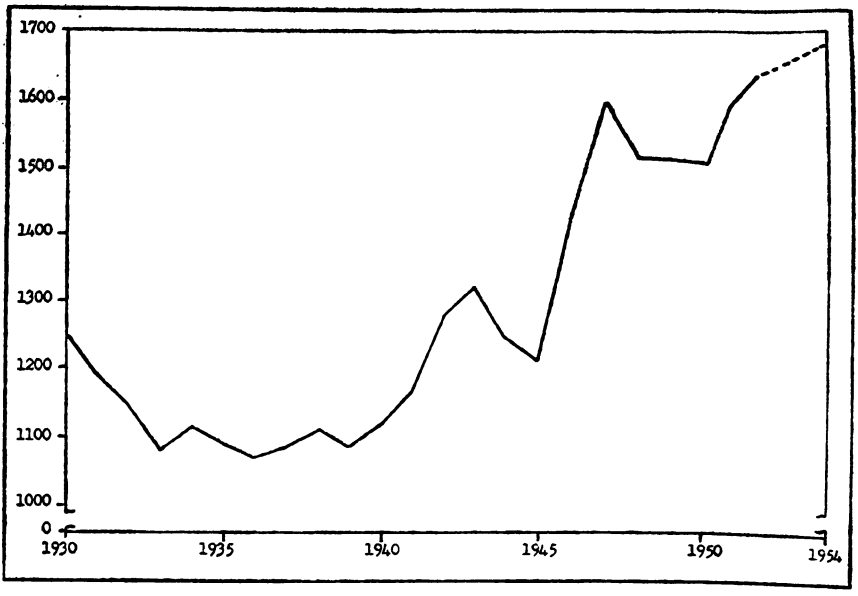



Fig. 8. Gross reproduction rate, United States, 1930–54. (Sources: 1930–39, United Nations, DEMOGRAPHIC YEARBOOK, 1954, page 456; 1940–52, United States, National Office of Vital Statistics, *Vital Statistics-Special Reports* 40(10), March 4, 1955; 1953–54, estimated by the writer on the basis of official preliminary birth reports.)

upward trend occur in connection with peaks following the depression and following the war. The behavior of the 1950's is presumably relatively unaffected by the occurrence of postponed births. If this time series were taken at face value, the bulk of fertility theory would have to be re-written. The purpose of the present paper has been to suggest a few methodological precautions which may make such a revision unnecessary.

## APPENDIX A

The relationship between the period crude birth rate and the period total fertility rate may be expressed in the following way:

Births to women aged a during the period concerned = $B(a)$;
Number of women aged a in the mean population for the period = $N'(a)$;
Mean population for the period (both sexes) = $N$;

$$\text{Crude birth rate} = b = \frac{\Sigma B(a)}{N}$$

$$\text{Total fertility rate} = F = \Sigma \left[\frac{B(a)}{N'(a)}\right]$$

Then $b/F = \Sigma[d(a) \cdot p(a)]$,

$$\text{Where } d(a) = 1/F \left[\frac{B(a)}{N'(a)}\right]$$

$$\text{and } p(a) = \left[\frac{N'(a)}{N}\right]$$

All summations are for the range of the childbearing ages.

Thus the relationship between the crude birth rate (b) and the total fertility rate (F) may be expressed as a weighted sum of the proportions of the total fertility rate contributed by each of the childbearing ages [d(a)], the weights being the proportions of the total population which are in those particular ages (and are female) [p(a)]. Since the customary shape of the age structure implies larger proportions of the population at younger ages, i.e., p(a) varying inversely with a, a tendency for the fertility of younger females to be enhanced relative to that for older females, i.e., for d(a) to become somewhat larger for the lower ages and somewhat smaller for the higher ages, will lead to a rise in b/F. Speaking empirically, the decline in the mean age of fertility in Sweden in the past century has had the effect of reducing the rate of decline of the crude birth rate relative to that of the total fertility rate.

## Appendix B

The period total fertility rates (Figure 2), the cohort total fertility rates (Figure 4) and the cohort mean ages of fertility (Figure 5) are based on female age-specific confinement rates for five-year age groups for five-year time periods, Sweden, 1751–1950. For the period 1751–1900 the source of these rates is Bevölkerungsstatistik Schwedens (Gustav Sundbärg, Stockholm, Norstedt, 1907). For the period 1901–1950 these rates have been gathered by the writer from the official yearbooks (Statistisk Årsbok) and publications of vital statistics (Befølkningsrörelsen) for the individual years. For the most recent cohorts plotted in the graphs, fertility rates at the older ages have been estimated by simple extrapolation procedures.

The calculations performed may be symbolized as follows: Fertility rate women of age i in time period $j = f_{i,j}$. Total fertility rate for period $j = \Sigma f_{i,j}$.

Total fertility rate for the cohort born in period $j = \Sigma f_{i,j+i}$.

Mean age of fertility for the cohort born in period $j = \left[\frac{\Sigma i \cdot f_{i,j+i}}{\Sigma f_{i,j+i}}\right] = \bar{i}_j$.

All summations are for the range of the childbearing ages. These equations are expressed in single-year form for the sake of convenience; for five-year age and time divisions the computation principle is exactly the same.

In the figures in the text, the cohort values for the various parameters have been plotted in alignment with the particular periods for which period parameters are available. Now the time span of childbearing of the cohort born in year j runs from the time corresponding to the cohort's earliest age of childbearing (say $j+15$) to the time corresponding to its latest age of childbearing (say $j+49$). For the purpose of comparison of cohort values with period values, it was decided arbitrarily (but not unreasonably) to date the particular cohort parameter at the time point corresponding to its mean age of fertility, in other words at the middle of its childbearing period by one definition. Thus the cohort born in year j was considered to have its fertility parameters located at time point $j+\bar{i}_j$. Values of each parameter were obtained for the times corresponding to the midpoints of the periods identified in the various graphs by linear interpolation between the values for the cohorts with dates bordering on either side of the required date. The only exception to this procedure is the graph of changes in the cohort mean age of fertility (Figure 7), for which a separate interpolation of values of the cohort mean age of fertility was undertaken for dates half-way between those plotted in the other graphs, so that the differences in successive cohort mean ages of fertility would be appropriately aligned in a temporal sense.

The relationship between the ordinate scales of Figures 6 and 7 is not arbitrary. By means of simple mathematical models it may be shown that a decline of the mean age of fertility by x years between two cohorts which are t years apart tends to give a period total fertility rate a value which is $(1+x/t)$ times the corresponding cohort total fertility rate. In the above empirical presentation, $t = 5$, so that a decline of, say, 0.5 years in the mean age of fertility between two successive cohorts tends to yield an index of timing distortion of 1000

$(1+0.5/5) = 1100$. In practice the indicated relationship is only approximately valid, primarily because the mean of the fertility-age distribution is inadequate to represent the complicated changes in the distribution of fertility through time which may actually be occurring from cohort to cohort.