This procedure gives most weight to alleles that apparently contain the most information about admixture (that is, the smallest variance associated with the admixture estimate). However, should there be perturbating factors influencing alleles associated with small variances, then the bias in the mean estimate of admixture may be considerable.
31. T. E. Reed, *Science* **165**, 762 (1969).
32. Recent evidence suggests the Duffy locus may be linked to a locus, such as skin color, at which assortative mating occurs in the black population [H. Gershowitz, *Amer. J. Hum. Genet.* **24**, 38a (1972)].
33. As an appropriate correction one could take into consideration the variance component due to genetic drift. Thus, with information about the size of the hybrid population, the number of generations involved, and the presumed parental composition, the distribution of the variance of gene frequencies through time could be obtained as a joint function of migration rate and genetic drift [compare M. Kimura, *Diffusion Models in Population Genetics* (Methuen, London, 1964), pp. 1–57].
34. For practically all the loci studied some kind of genotype-viability or genotype-fertility has been postulated [see Cavalli-Sforza and Bodmer (*8*), pp. 1–965].
35. Supported in part by PHS grant GM 18840 and Atomic Energy Commission contract AT(11-1)-1552. We have profited from discussions with H. Gershowitz, J. Neel, T. Reed, C. Sing, R. Spielman, and P. Workman.

Racial Aspects of Zero Population Growth

Ernest B. Attah

The possibility of zero growth in the population of the United States has stimulated some recent investigations (*1–3*) of the implications of alternative paths to that condition, based on projections of the population as a whole. Given the history (*4*) of marked differentials in fertility and mortality rates between the white and nonwhite segments of the population, this article is concerned with the consequences of different rates of approach to zero growth. Specifically, what would be the effects of different rates on the short- and long-term growth of the respective segments of the population? How long would it take the population to stabilize, and how much would the population have increased by then? What intermediate trends would appear in the proportion of nonwhites in the population, and what would be the relative sizes of the white and nonwhite segments in the long run?

These questions are explored on the basis of separate projections of the white and nonwhite segments of the population, incorporating different assumptions about the patterns through which zero growth is attained (intermixture of the two segments is not considered). The assumptions are based on alternative trends in the reproduction rate, considered in terms of the interaction between alternative fertility and mortality trends.

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Modeling Approach

Since the discussion will mainly emphasize large-scale and long-term questions, it will be sufficient to work with only the main demographic factors of population growth for these projections. Like Frejka (*1*, p. 380), I shall "ignore factors which can play important roles in the short run, but which seem fairly stable in the long run (changes in proportion married, changes in average age at marriage, etc.)" and base the projections only on fertility rates, mortality rates, and reproduction rates. Model specification will turn primarily on the net reproduction rate (N) and will take the form of alternative assumptions about the speed with which replacement rates of fertility ($N = 1.0$) are attained, beginning from the initial date. Fertility rates will be assumed to remain indefinitely at replacement once that is attained. Zero population growth will thereby emerge with time, as stipulated by the theory of stable populations (*5*).

The initial year for all projections is 1965. Thus the initial demographic characteristics of both the white and nonwhite populations are those of 1965, shown in Tables 1 and 2. To simplify the arithmetic, projections are carried out for the female population only. For present purposes, it is sufficient simply to double the projected female population in order to obtain the corresponding total population. Projections are generally made for 5-year intervals and extend for about 200 years. Five separate projections, based on a fixed pattern of mortality decline combined with five different patterns of fertility decline, have been made for each of the white and nonwhite populations. Fertility rates predominate heavily over mortality rates, with respect to influencing possible zero growth. I therefore emphasize in these projections the effects of alternative trends in fertility.

Assumptions about mortality are based on the life expectancy at birth (e_0), which provides a convenient summary measure of the overall circumstances of sickness and death, over the entire span of life, in a given population (*6*). For the white population, life expectancy is assumed to increase linearly (by 6 months each period) over five projection periods after the initial period, until it attains a fixed level of 77.5 years [for convenience, life expectancy in the initial period is set at 75.0 years (Table 2)]. For the nonwhite population (life expectancy in the initial period set at 67.5 years), the assumed linear increase in life expectancy occurs in two stages: first with a 1-year increase each period up to a life expectancy of 74.5 years; then with a 6-month increase each period until the final, fixed level of 77.5 years is attained. The supporting argument for these assumptions is that, whereas mortality rates in the white population in 1965 are already quite low and future declines are therefore likely to be gradual, the corresponding rates in the nonwhite population are high enough that there is room for relatively rapid declines until rates similar to those for whites in 1965 are attained, after which declines may follow the same pattern as in the white population. The same final life ex-

Table 1. Female age structure and age-specific maternity rates of the white and nonwhite populations: 1965.

Population	Birth–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80+	Total
	Age (years)																	
	*Female age structure (percentage distribution)**																	
White	9.65	9.91	9.22	8.42	6.87	5.74	5.61	6.18	6.54	6.08	5.63	4.96	4.30	3.65	3.09	2.20	1.96	100.0
Nonwhite	13.67	12.55	11.08	9.10	7.00	6.02	5.92	6.12	5.86	5.07	4.54	3.64	3.06	2.15	1.88	1.20	1.17	100.0
	Age-specific maternity rates†																	
White				0.0295	0.0923	0.0772	0.0446	0.0214	0.0058	0.0003								
Nonwhite				0.0671	0.1219	0.0928	0.0583	0.0315	0.0095	0.0007								

* Source: U.S. Bureau of the Census, *Current Population Reports*, series P-25, No. 321 (Government Printing Office, Washington, D.C., 1965), table 1, pp. 11–14. † Source: U.S. Public Health Service, *Vital Statistics of the United States, 1965*, vol. 1, *Natality* (Government Printing Office, Washington, D.C., 1967), table 1-6, p. 1-7.

pectancy is assumed for both populations, in order to simulate long-range equalization of the general incidence of sickness and death among their members. Table 3 displays the assumed trends in mortality and fertility rates for the different projections.

The five projections carried out for each of the white and nonwhite populations are based on the assumptions that, beginning from 1965, replacement rates of fertility are attained: instantly (projection 1); in 15 years (projection 2); in 35 years—that is, by the year 2000 (projection 3); in 55 years (projection 4); and in 75 years (projection 5). For projections 2 through 5, the net reproduction rate is assumed to decline linearly over the interval. The corresponding gross reproduction rates (G) also decline linearly between initial rates and the rates they have reached when net reproduction rates first reach replacement (*7*). Given the final rates at which mortality is assumed to remain fixed (with $e_0 = 77.5$ years), the fertility rates needed for replacement are $G = 1.01$. Corrected for the sex ratio at birth, this means that women who live through their childbearing years would tend to have, on the average, just about two children (*8*). These assumed final rates are the same for all the different projections of the white and nonwhite populations.

As for the modeling approach, it is clear, first of all, that the assumptions imply substantial reductions in fertility for both the white and nonwhite populations. Given its higher initial fertility rates, the reductions are greater for the nonwhite population than for the white. For example, the initial total fertility rates (Table 2) imply averages of close to three children per woman for whites, and almost four for nonwhites, but these rates are eventually reduced to about two children for both populations.

The speed with which these reductions are assumed to occur also varies. In projection 1, they are assumed to occur instantly. Such instantaneous cuts in fertility rates would be quite drastic. However, the other projections are progressively less drastic. Although current overall rates are the lowest ever, the recorded trends in white and nonwhite fertility in the years shortly before and since 1965 are approximated by the assumptions for projection 2 (*9*). The question is whether the model includes a wide enough range of assumptions for likely future trends. For example, what if fertility rates where to remain below replacement? It is hazardous to try to guess the actual future trends of fertility rates; however, it seems reasonable to argue that they are not likely to remain below replacement for long. Placing the past experience of this country and several European countries in the perspective of probable future conditions, it seems likely that future fertility rates will fluctuate around replacement (*10*). Therefore, for the purposes of the long-range factors with which this discussion is concerned, the assumption of steady replacement rates of fertility represents a plausible "average."

A final note on the modeling approach concerns the standard features of single-sex population projection—namely, that migration is not considered and that the modeling assumptions are essentially arbitrary. The effect of migration on future population growth is ignored for the purpose of examining the implications of mortality and fertility conditions independently of any other factors. The modeling assumptions are based only on these two factors, and the resulting projections elaborate the assumptions. Inasmuch as these assumptions are necessarily arbitrary, the advantage of models is that they make it possible to develop concrete simulations of the logical outcomes of a wide range of conditions, which can be chosen at will for the purposes of study and discussion.

Results

Table 4 contains data on the long-term growth of the projected populations. Perhaps the first striking characteristic of these populations is that they all increase considerably in size before eventually stabilizing. Some of this increase is caused by the assumed mortality declines, but the bulk of the continued population growth results from the nature of the initial age structure: relatively large numbers of women were in the younger age groups in 1965 (Table 1), and, even if they began instantly to reproduce at replacement levels, as in projection 1, they would still produce enough offspring to increase the total size of the population substantially. Indeed, other data (not reported here) indicate that the average annual growth rates of the projected populations actually tend to increase slightly in the first 10 to 20 years after the initial date and then begin to decline toward zero. Thus the legacy of past growth in the population is a built-in momentum for future growth.

Given its younger initial age structure, the nonwhite population has a greater momentum toward growth than does the white population. As a result, the peak size of the nonwhite population in each projection is proportionately greater, compared to its initial size, than is that of the corresponding white population. Similarly, as a result of the successive delay in fertility reduction over the five separate projections, the peak size attained by each of the populations before stabilization becomes progressively greater in relation to its initial size. The combination of growth momentum and delay in fertility reduction for the nonwhite projection 5, for example, results in continued growth of the population to a final size 4.24 times the initial size. Beginning from the period in which replacement fertility is first assumed to obtain, the populations continue to grow for at least 60 years before finally attaining their peak sizes —in one case (nonwhite projection 1), for as long as 95 years.

Tables 5 and 6 deal with the convergence of the projected populations toward a stationary age structure. The stationary age structure (with $e_0 = 77.5$ years and $G = 1.01$) (*11*), is the same for all projections. Given the combination of lower fertility rates and higher survivorship ratios, the proportion of young persons under age 15 is much lower in the stationary population (19.2 percent) than in the initial white (28.8 percent) and nonwhite (37.3 percent) populations. The proportion of persons age 65 and older is higher in the stationary population (18.5 percent) than in the initial white (10.9 percent) and nonwhite (6.4 percent) populations. Thus a general shift would have to take place in the orientation of social welfare programs, from a primary emphasis on the need to provide for the young toward an increased concern with problems of the old. This shift would be greater for the nonwhite population than for the white, given the younger initial age structure of the former. Interestingly, however, the combined proportion of young and old would not differ greatly between the initial white population (39.7 percent) and the stationary model (37.7 percent), but it would be noticeably reduced for the nonwhite population (43.7 percent initially; 37.7 percent for the stationary model).

Convergence of the projected populations toward the stationary age structure is evaluated on the basis of the index of dissimilarity. Defined as half the sum of the absolute differences between two percentage distributions (*12*), this index indicates the extent to which one of the distributions would have to be rearranged in order to reproduce the other. Its values may range from zero for identical distributions to 100 percent for totally dissimilar distributions. With the populations grouped by age, the same as in Tables 5 and 6, the values of the index of dissimilarity between the initial age structures and the stationary form are 11.5 percent for the white population and 21.2 percent for the nonwhite.

The values of the index decline steadily as the projected populations approach the stationary age structure. Having the earliest assumed fertility reduction, projection 1 converges fastest of the five projections. And, given the younger initial age structure of the nonwhite population, projections for that population are more dissimilar to the stationary model at each stage than are

Table 2. Selected demographic characteristics of the white and nonwhite populations: 1965.

Population	Total fertility rate*	Gross reproduction rate†	Net reproduction rate†	Mean age of child-bearing‡	Female life expectancy at birth (years)§	Total population (millions)¶
White	2.790	1.357	1.314	25.9	74.7	171.4
Nonwhite	3.891	1.919	1.802	25.0	67.4	23.1

* Source: U.S. Public Health Service, *Vital Statistics of the United States, 1965*, vol. 1, *Natality* (Government Printing Office, Washington, D.C., 1967), table 1-6, p. 1-7. † Source: *ibid.*, table 1-4, p. 1-5. ‡ Source: *ibid.*, table 1-12, p. 1-12. § U.S. Bureau of the Census, *Statistical Abstract of the United States: 1967* (Government Printing Office, Washington, D.C., 1967), table 61, p. 53. ¶ U.S. Bureau of the Census, *Current Population Reports*, series P-25, No. 321 (Government Printing Office, Washington, D.C., 1965), table 1, pp. 11–14.

Table 3. Basic modeling assumptions: trends in female life expectancy at birth (e_0) and net reproduction rates (N), in the white and nonwhite populations, for projections 1 through 5.

Period	White						Nonwhite					
	e_0	N					e_0	N				
		1	2	3	4	5		1	2	3	4	5
1965–70	75.0	1.00	1.24	1.28	1.30	1.31	67.5	1.00	1.59	1.69	1.72	1.74
1970–75	75.5		1.16	1.25	1.27	1.29	68.5		1.40	1.60	1.66	1.70
1975–80	76.0		1.08	1.21	1.25	1.27	69.5		1.20	1.50	1.61	1.66
1980–85	76.5		1.00	1.17	1.22	1.25	70.5		1.00	1.41	1.55	1.62
1985–90	77.0			1.13	1.20	1.23	71.5			1.31	1.48	1.57
1990–95	77.5			1.08	1.17	1.21	72.5			1.21	1.42	1.53
1995–2000				1.04	1.14	1.19	73.5			1.11	1.35	1.48
2000–05				1.00	1.11	1.17	74.5			1.00	1.29	1.43
2005–10					1.08	1.15	75.0				1.21	1.38
2010–15					1.06	1.13	75.5				1.14	1.33
2015–20					1.03	1.11	76.0				1.07	1.27
2020–25					1.00	1.08	76.5				1.00	1.22
2025–30						1.06	77.0					1.17
2030–35						1.04	77.5					1.11
2035–40						1.02						1.06
2040–45						1.00						1.00

Table 4. Long-term growth of the population: projections 1 through 5 for the white and nonwhite populations (N is net reproduction rate).

Projection	$N = 1.00$ from the year	Peak is reached in	Years from first $N = 1.00$ to peak (No.)	Peak size (millions)	Percent of 1965 population
			White		
1	1965	2035	70	231.6	135
2	1980	2055	75	250.0	146
3	2000	2060	60	280.1	163
4	2020	2085	65	314.0	183
5	2040	2100	60	351.9	205
			Nonwhite		
1	1965	2060	95	37.8	164
2	1980	2055	75	44.8	194
3	2000	2065	65	57.8	250
4	2020	2080	60	75.0	325
5	2040	2100	60	98.0	424

Table 5. Female age structure of model stationary population [source: West model stationary population, mortality level 24; A. J. Coale and P. Demeny, *Regional Model Life Tables and Stable Populations* (Princeton Univ. Press, Princeton, N.J. 1966), part 2, p. 72].

Population	Age (years)									
	Birth–4	5–9	10–14	15–19	20–29	30–44	45–64	65–74	75+	Total
Percentage	6.4	6.4	6.4	6.4	12.7	19.0	24.2	10.2	8.3	100.0

Table 6. Convergence of projected populations (1 through 5): indices of dissimilarity (see text) between age structure of stationary and projected populations, for selected years.

Year	White					Nonwhite				
	1	2	3	4	5	1	2	3	4	5
1970	11.4	12.1	12.3	12.3	12.4	20.1	21.8	22.1	22.3	23.4
1985	9.8	10.5	11.4	11.9	12.0	15.9	18.6	21.1	22.0	22.5
2000	5.5	7.1	8.9	10.0	10.4	10.7	14.2	17.7	19.6	19.8
2015	3.4	4.2	5.3	7.2	8.2	6.4	6.9	11.4	15.2	16.2
2030	1.7	0.8	1.1	4.1	5.5	3.0	2.5	5.0	9.5	16.1
2045	0.6	0.2	1.0	2.2	3.9	1.0	0.4	2.2	4.8	9.0
2060	0.2	0.1	0.1	0.6	1.8	0.4	0.3	0.4	2.0	4.7
2075	0.2	0.1	0.1	0.3	0.9	0.4	0.4	0.5	0.5	2.1

the corresponding projections of the white population. In all cases, however, the age structures of the projected populations essentially become stationary about 65 to 70 years after replacement fertility is first assumed to obtain.

To evaluate the consequences for the total population if the white and nonwhite segments moved separately toward zero growth through the alternative paths represented by the different projections, five combinations will be studied: (1,1), (3,3), (5,5), (1,5), and (5,1), where the first number in each pair refers to the projection of the white population, the second to the nonwhite. The first three ("matched") pairs involve simultaneous attainment of replacement fertility, whether immediately (1,1), in the middle range (3,3), or in the long range (5,5). The last two pairs represent instant attainment of replacement fertility in the white segment but not until the long run in the nonwhite (1,5), and vice versa (5,1). Table 7 shows the general characteristics of the total populations resulting from these combinations. In keeping with the trends in the separate projected populations, these combined populations also increase in size for some time before stabilizing, and their growth rates also rise slightly in the first 10 to 20 years before beginning the decline toward zero (*13*).

The total populations resulting from the "matched" pairs of projections continue to grow for at least 70 years (1,1) after the initial date before stabilizing —and in the case of (5,5), for well over 100 years. The average annual growth rates in all three cases follow the same trend, but the rate at each stage is lowest in (1,1), second in (3,3), and highest in (5,5) because of the successive delay in reaching replacement fertility. The total population (white and nonwhite) size at each stage, as well as the peak population sizes, are also ranked in the same order.

The proportion of nonwhites in these total populations is similarly ranked at each stage, and increases over time for all three of the "matched" projections. Primarily because of its younger initial age structure, and secondarily because of its higher fertility rates at each stage before replacement is attained, the nonwhite population possesses a proportionately greater momentum of growth than does the white, with the result that it grows faster than the white population at each stage before stabilization, and its proportion of the total population thereby increases. This result is suggested in Table 4, where the percent of increase between initial and peak size is seen to be greater in the projected nonwhite populations than in the corresponding white populations. Therefore, if the white and nonwhite segments of the population simultaneously attained replacement fertility, the percentage of nonwhites in the total population would increase somewhat over time. The longer it took to arrive at replacement fertility, the larger this percentage would be: 14 percent if instantly, 17 percent if by the year 2000, and over 20 percent if not for 75 years from the initial date.

The total populations that result from the (1,5) and (5,1) combinations also stabilize eventually at zero rates of growth, but they approach this condition in different ways. In the case where the nonwhite population attains replacement fertility instantly and the white population only does so in the long run (5,1), the average annual growth rates rise in a manner similar to the "matched" combinations and then decline steadily toward zero. But in the case where the white population instantly attains replacement fertility and the nonwhite population only does so in the long run (1,5), the average annual growth rates rise, begin to fall, and then rise again slightly under the increasing influence of the still rapidly growing nonwhite population before finally falling again. In both cases, the total populations continue to grow until the end of the next century, by which time the size attained is almost 70 percent larger than the initial size in one case (1,5) and twice the initial size in the other (5,1). The number of persons added to the population before it ceases to grow is about 135 million in the (1,5) case, but in the opposite case, (5,1), an additional 60 million persons would have been added before the population finally stopped growing.

The trends in the percentage of nonwhites in these two combinations of projections reflect the different growth trends of the white and nonwhite populations. Nonwhite projection 5 grows much faster and to a larger final size, relative to the initial size, than does white projection 1 (Table 4), with the result that the proportion of nonwhites in (1,5) increases steadily, stabilizing at just under 30 percent. In (5,1), however, relative increases are reversed, and the proportion of nonwhites decreases finally to just under 10 percent.

A brief comparison of the five different combinations of projections in Table 7 shows the following: in terms of the demographic characteristics of the total population, (1,1) and (5,5) effectively provide the low and high extremes, respectively, with (3,3) falling between them. Although both (1,5) and (5,1) involve extreme conditions with respect to the different segments of the population, their resulting combined populations still fall between the extremes represented by (1,1) and (5,5). The demographic characteristics of the (1,5) and (5,1) combinations are actually quite similar to the characteristics of the (3,3) combination. All other pairings of the five separate projections for each of the white and nonwhite segments would, with respect to their demographic characteristics, produce total populations between (1,1) and (5,5).

These combinations of projections are useful for developing perspectives on the relative contributions that the white and nonwhite segments would make to future population growth as the total population moved toward zero growth. First of all, the peak population sizes attained by the "matched" combinations indicate that the white segment is clearly preponderant in the total population, even though the nonwhite segment grows faster than the white at each stage. The ratios of peak to initial sizes for these three combinations are 1.38 (1,1), 1.73 (3,3), and 2.31 (5,5), which clearly contrast with the separate ratios (Table 4) for each segment. Similarly, in spite of its faster rate of growth, the nonwhite segment still remains a minority of the population for all three combinations. Therefore the bulk of the total population increment in every case may be attributed to the growth of the white segment.

In sum, these combinations of projections point to the continued preponderance of the white segment over the nonwhite, with respect to influence on total population growth before reaching zero growth. Even under the conditions of (1,5), the nonwhite segment would contribute considerably less to population growth than would the white.

The combinations of projections in Table 7 are also useful in determining the likely proportion of nonwhites in the total population for alternative paths to zero population growth. As described above, the percentage of nonwhites increases steadily in the "matched" combinations. In the other two, it rises steadily in one case (1,5), and falls in the other (5,1). Remarkably, however, this proportion still does not, in the long run, exceed 30 percent in the one case, nor fall much below 10 percent in the other. Therefore, it seems likely that the percentage of nonwhites in the total population will continue to increase on any realizable path toward zero population growth. It would require conditions at least as extreme as those embodied in (5,1) for this proportion to decrease.

Extensions

The general frame of these models can be extended to other substantive issues connected with race and zero population growth. Three specific issues will be discussed here: the "genocide" hypothesis, the possibility of nonwhite

Table 7. Characteristics of the total population for given combinations of white and nonwhite (respectively) population projections.

Period	Combinations														
	(1,1)			(3,3)			(5,5)			(1,5)			(5,1)		
	Growth rate	Size* (millions)	Nonwhite (%)	Growth rate	Size* (millions)	Nonwhite (%)	Growth rate	Size* (millions)	Nonwhite (%)	Growth rate	Size* (millions)	Nonwhite (%)	Growth rate	Size* (millions)	Nonwhite (%)
1965–70	0.56	203.0	12.2	1.01	207.6	12.5	1.05	208.0	12.5	0.69	204.3	12.7	0.92	206.7	12.0
1970–75	0.69	210.0	12.3	1.10	219.3	13.0	1.17	220.4	13.0	0.83	212.8	13.5	1.04	217.6	11.9
1975–80	0.80	218.5	12.5	1.15	232.1	13.4	1.26	234.6	13.6	0.94	222.9	14.3	1.13	230.2	11.9
1980–85	0.80	227.3	12.8	1.10	245.0	13.8	1.25	249.4	14.1	0.95	233.5	15.1	1.11	243.2	11.9
1985–90	0.66	235.0	12.9	0.96	257.0	14.3	1.15	264.1	14.7	0.83	243.4	15.9	1.00	255.7	11.9
1990–95	0.51	241.1	13.1	0.83	267.9	14.7	1.07	278.6	15.3	0.71	252.1	16.9	0.91	267.6	11.8
1995–2000	0.43	246.2	13.2	0.73	277.7	15.0	1.03	293.2	15.9	0.65	260.2	17.9	0.86	279.2	11.7
2005–10	0.41	256.5	13.5	0.65	296.2	15.6	1.00	324.1	17.1	0.64	277.1	20.0	0.83	303.5	11.4
2015–20	0.30	265.3	13.7	0.54	313.8	16.1	0.88	355.0	18.1	0.54	293.3	22.0	0.72	327.0	11.1
2025–30	0.09	269.0	13.9	0.32	325.6	16.5	0.67	381.7	19.2	0.82	304.7	24.0	0.51	346.0	10.8
2035–40	– 0.02	268.8	14.0	0.18	332.4	16.8	0.50	402.8	20.0	0.21	311.8	25.8	0.36	359.8	10.4
2045–50	0.03	269.0	14.0	0.11	336.5	17.0	0.39	419.5	20.6	0.21	317.8	27.2	0.29	370.7	10.2
2070–75	0.00	268.6	14.0	0.00	337.6	17.1	0.14	444.2	21.6	0.07	326.8	29.3	0.10	386.0	9.7
2095–2100	– 0.01	268.0	14.0	– 0.01	336.9	17.0	0.01	449.9	21.8	– 0.01	328.6	29.8	0.01	389.3	9.6
2120-25	– 0.01	267.5	13.9	– 0.01	336.1	17.0	0.00	449.0	21.7	– 0.01	327.8	29.7	0.00	388.7	9.6
2145-50	– 0.01	266.9	13.9	– 0.01	335.3	16.9	– 0.01	447.8	21.6	– 0.01	326.8	29.6	– 0.01	387.9	9.5

* Size of the total population at the end of the period.

Table 8. Selected features of the "genocide hypothesis" projection (e_0 is female life expectancy at birth; G is gross reproduction rate; N is net reproduction rate).

Period	Modeling assumptions			Population at end of period (millions)	Average annual growth rate during period
	e_0	G	N		
1965–70	67.5	1.81	1.67	25.9	1.72
1970–75		1.69	1.57	28.3	1.77
1975–80		1.58	1.46	30.8	1.76
1980–85		1.47	1.36	33.4	1.63
1985–90		1.35	1.25	35.8	1.40
1990–95		1.24	1.15	38.0	1.18
1995–2000		1.13	1.04	39.9	0.98
2000–05		1.01	0.94	41.5	0.78
2005–10				43.0	0.75
2015–20				45.7	0.55
2025–30				47.2	0.24
2035–40				47.6	0.02
2045–50				47.1	−0.12
2070–75				44.2	− 0.29
2095–2100				41.2	− 0.28
2120–25				38.4	− 0.28
2145–50				35.8	− 0.28

growth to majority, and the "smoke-screen" hypothesis.

The "genocide" question refers to the fear, expressed by a number of people within the black community (*14, 15*) that advocacy of fertility limitation among blacks may be aimed toward effecting a reduction in their numbers and strength, or even possibly at totally exterminating them. The particular word "genocide" is perhaps strong in this connection, but the substantive point at issue concerns the likely consequences of sustained fertility reduction in the nonwhite population.

In a sense, all of my projections are related to this issue, inasmuch as they all involve substantial fertility reductions over time. However, their relevance is limited by the final assumption in all cases of fixed, replacement rates of fertility after some period. It is therefore necessary to devise new projections that would allow fertility and mortality trends to be modeled separately—so that, for example, net reproduction rates in the nonwhite population would fall below replacement. The new modeling assumptions are shown in the second, third, and fourth columns of Table 8.

The female life expectancy at birth is assumed to remain fixed at the initial level. Independently, the gross reproduction rate is assumed to decline linearly to a final rate of 1.01, attained at the turn of the century. This final rate is the same as those for projections 1 through 5 above. With mortality fixed, the resulting trend in net reproduction rates is also one of linear decline (*7*), to a final level of 0.94. These assumptions essentially simulate the eventual attainment of sustained, below-replacement fertility in the nonwhite population, with the trends in mortality and fertility being chosen at extremes for the purpose of establishing logical bounds.

The last two columns of Table 8 show the trends in size and average growth rate of the resulting projected population. Even under below-replacement conditions, this population continues to grow for 75 years after the initial date, attaining a peak at more than double its initial size before beginning to decline. The growth momentum inherent in the initial age structure is so strong, in fact, that the average annual growth rates rise in the early period before beginning to fall under the influence of the reduction in net reproduction rates.

In Table 9, this new projection of the nonwhite population (Gen) is combined with projections 1, 3, and 5 of the white population in order to study the consequences for the total population if the white segment evolved toward zero growth while the nonwhite segment evolved as in the "genocide hypothesis" projection. The basic demographic characteristics of the combined populations display much the same trends as before. The average annual growth rates rise slightly in the early period, for all combinations, and then begin to decline. Similarly, the total population

Table 9. Characteristics of the total population for given combinations of white population projections and the "genocide hypothesis" projection.

Period	(1,Gen)			(3,Gen)			(5,Gen)		
	Growth rate	Size* (millions)	Nonwhite (%)	Growth rate	Size* (millions)	Nonwhite (%)	Growth rate	Size* (millions)	Nonwhite (%)
1965–70	0.68	204.2	12.7	1.01	207.6	12.5	1.04	207.9	12.5
1970–75	0.80	212.4	13.3	1.09	219.2	12.9	1.14	220.0	12.9
1975–80	0.89	221.9	13.9	1.14	231.8	13.3	1.26	233.6	13.2
1980–85	0.88	231.7	14.4	1.08	244.5	13.7	1.18	247.6	13.5
1985–90	0.74	240.4	14.9	0.94	256.1	14.0	1.06	261.1	13.7
1990–95	0.58	247.5	15.4	0.80	266.6	14.2	0.96	274.0	13.9
1995–2000	0.48	253.5	15.7	0.70	275.9	14.5	0.89	286.5	13.9
2005–10	0.44	264.8	16.2	0.60	293.1	14.7	0.84	311.8	13.8
2015–20	0.32	274.6	16.6	0.49	309.1	14.8	0.72	336.3	13.4
2025–30	0.10	278.8	16.9	0.27	319.1	14.8	0.51	355.8	13.3
2035–40	− 0.02	278.8	17.1	0.12	324.0	14.7	0.35	369.8	12.9
2045–50	0.00	278.4	16.9	0.06	326.3	14.4	0.27	380.1	12.4
2070–75	− 0.05	275.2	16.1	− 0.04	324.1	13.6	0.06	392.6	11.3
2095–2100	− 0.05	271.8	15.2	− 0.04	320.7	12.8	− 0.02	393.1	10.5
2120–25	− 0.05	268.7	14.3	− 0.04	317.5	12.1	− 0.03	389.9	9.8
2145–50	− 0.05	265.7	13.5	− 0.04	314.4	11.4	− 0.04	386.7	9.3

* Size of the total population at the end of the period.

sizes reach their peak for each combination and then begin to decline slowly under the influence of the nonwhite population. Because of the successive delay of fertility reduction in the white population, the growth rates and population sizes at each stage are higher in the (3,Gen) combination than in (1,Gen), and so forth. Strikingly, the relative distribution of growth momentum is such that, even under the assumed conditions, the projected nonwhite population grows faster than the white population in the early period, with the result that the proportion of nonwhites in the total population increases for some time before beginning to decline. This result holds even in the case of (5,Gen), where the reduction in white fertility occurs only after some time. Thus, in spite of a drastic reduction in fertility and unchanging mortality rates, the projected nonwhite population continues to grow, both absolutely and relatively, for a while. It therefore seems likely that the real nonwhite population will do the same in any probable future course of mortality and fertility rates.

Concerning the particular question of "genocide," a quick arithmetic calculation yields an interesting result. Projection of the nonwhite population size to zero would involve infinity, so extinction will be defined as that point when all that remains of the population is one couple who subsequently fail to replace themselves. Thus the problem is reduced to determining how long the projected population requires to decrease to size two. The final, fixed rate of decrease is 0.28 percent per year, attained in the year 2100. From that point on, it would take approximately 6015 years for the nonwhite population to become extinct.

Conversely, what would be the consequences of unchecked growth of the nonwhite population while the white population progressed to zero growth? The modeling technique in this case is to keep nonwhite fertility levels up while reducing mortality. The assumptions are shown in the second, third, and fourth columns of Table 10. The female life expectancy at birth is assumed to increase at the rapid rate of 1.5 years each projection period until it attains 75 years, after which it increases by 6 months each period. The final level of 77.5 years is the same as in projections 1 through 5. The gross reproduction rate is assumed to remain at the initial level (*16*), and the net reproduction rate consequently rises steadily to a final level of 1.89.

Table 10. Selected features of the nonwhite "majority" projection (e_0 is female life expectancy at birth; G is gross reproduction rate; N is net reproduction rate).

Period	Modeling assumptions			Population at end of period (millions)	Average annual growth rate during period
	e_0	G	N		
1965–70	67.5	1.94	1.80	26.1	1.91
1970–75	69.0	1.94	1.82	29.1	2.16
1975–80	70.5	1.94	1.84	32.7	2.36
1980–85	72.0	1.94	1.86	36.8	2.43
1985–90	73.5	1.94	1.87	41.5	2.41
1990–95	75.0	1.92	1.88	46.7	2.41
1995–2000	75.5	1.92	1.88	52.8	2.45
2000–05	76.0	1.92	1.89	59.7	2.50
2005–10	76.5			67.6	2.53
2010–15	77.0			76.7	2.55
2015–20	77.5			87.0	2.55
2025–30				111.6	2.52
2035–40				142.9	2.50
2045–50				183.1	2.51
2070–75				340.0	2.51
2095–2100				631.1	2.51
2120–25				1171.7	2.51
2145–50				2175.4	2.51

As shown in the last two columns of Table 10, the projected nonwhite population (Maj) is characterized by a continually rising rate of growth and a correspondingly rapid increase in size. When combined (Table 11) with projections 1, 3, and 5 for the white population, this projected nonwhite population eventually assumes dominance of the demographic characteristics of the total population. The average annual growth rates rise in the early period and then begin to fall, under the influence of the white segment. But they begin to rise again after a while, this time under the influence of the rapidly growing nonwhite segment. The size of the total population also increases steadily for all combinations.

The proportion of nonwhites in the total population rises steadily in all combinations, since the projected nonwhite population continually grows faster than any of the projected white populations. The rate of increase in the percentage of nonwhites also increases as the white populations begin to stabilize at zero rates of growth while the nonwhite population continues to grow at a relatively high rate. In all cases, the percentage of nonwhites exceeds 50 after about 2065.

A third issue to consider is the view (*17*) that the theme of population limitation is employed as a diversionary tactic. The basic argument runs as follows: in the long run, it will be necessary to limit the growth of the population; therefore, it might be useful to initiate now some action toward that goal. However, population growth is a long-range problem requiring long-range approaches and should therefore not occupy all, or even most, of the problem-solving resources of the society. Rather, attention should be addressed to solving distributive problems, which are inflicting real hardships upon the excluded minorities on an immediate and continuing basis. Furthermore, all the available data indicate that, as these minorities begin to participate more fully in society, their fertility rates begin to decline drastically. For these reasons, primary emphasis at this time should be placed not on the overall need for fertility reduction, but on finding ways of making a fuller share of social amenities accessible to these minorities. If the opposite emphasis is adopted, then the conclusion cannot be escaped that the issue of population growth and the need for fertility limitation are essentially a smokescreen for the more important problem of redistribution, which, for whatever reasons, appears more difficult to solve.

The models that have been developed here do not bear directly on this issue, but, by their nature, they provide some indirect commentary on it. These models have been concerned with the consequences of alternative future demographic trends on the part of the white and nonwhite segments of the population, given their history of marked differentials in vital rates. Thus the modeling process underscores the fact that distributive issues arise even in the technical consideration of long-term problems of population growth. A

Table 11. Characteristics of the total population for given combinations of white population projections and the nonwhite "majority" projection.

Period	Combinations								
	(1,Maj)			(3,Maj)			(5,Maj)		
	Growth rate	Size* (millions)	Nonwhite (%)	Growth rate	Size* (millions)	Nonwhite (%)	Growth rate	Size* (millions)	Nonwhite (%)
1965–70	0.71	204.4	12.8	1.04	207.8	12.6	1.06	208.1	12.5
1970–75	0.86	213.2	13.6	1.14	220.0	13.2	1.20	220.8	13.2
1975–80	0.99	223.8	14.6	1.22	233.7	14.0	1.30	235.5	13.9
1980–85	1.01	235.1	15.6	1.20	247.9	14.8	1.30	251.0	14.7
1985–90	0.92	246.1	16.9	1.11	261.8	15.8	1.23	266.8	15.6
1990–95	0.82	256.2	18.2	1.02	275.3	17.0	1.17	282.7	16.5
1995–2000	0.82	266.4	19.8	0.98	288.8	18.3	1.16	299.4	17.6
2005–10	0.88	289.4	23.4	0.99	317.7	21.3	1.20	336.4	20.1
2015–20	0.91	315.9	27.5	0.99	350.4	24.8	1.16	377.6	23.0
2025–30	0.87	343.2	32.5	0.92	383.5	29.1	1.07	420.2	26.6
2035–40	0.94	374.1	38.2	0.94	419.3	34.1	1.05	465.1	30.7
2045–50	1.13	414.4	44.2	1.05	462.3	39.6	1.10	516.1	35.5
2070–75	1.49	571.0	59.5	1.38	619.9	54.8	1.30	688.4	49.4
2095–2100	1.84	861.7	73.2	1.74	910.6	69.3	1.62	983.0	64.2
2120–25	2.10	1402.0	83.6	2.03	1450.8	80.8	1.93	1523.2	76.9
2145–50	2.27	2405.3	90.4	2.22	2454.0	88.6	2.16	2526.3	86.1

* Size of the total population at the end of the period.

wide range of social and economic differentials also exist between the white and nonwhite segments of the population. Therefore, a full view of population limitation problems must include systematic consideration of the interrelations between the demographic differentials and the wider social and economic differentials.

As the Commission on Population Growth and the American Future has concluded (*2*, p. 71): "This nation cannot hope to successfully address the question of future population without also addressing the complex network of unemployment, poor housing, poor health services, and poor education, all of which act upon, and react to, the pressures of population."

Discussion

The Commission on Population Growth and the American Future recommended in its report that the nation "welcome and plan for" eventual stabilization of the population. Consideration of the speed with which that goal may be achieved leads to questions about the roles of the different segments of society in the process. In essence, do the demographic trends in segments of the population effectively contribute to or hinder rapid attainment of zero population growth?

Thus arises a familiar problem (*18*): To what extent are the different groups willing to undertake measures such as rapid fertility reduction for the purpose of benefiting the society as a whole? The answer to this question is far from predetermined, particularly in view of the exclusion and denial that have typified the relation of the nonwhite minority of the United States to the rest of the society. For example, it is not impossible to imagine minority opposition to fertility limitation among their populations for the express purpose of opposing officially sanctioned views. The population commission has noted (*2*, p. 61), in fact, that "population problems cannot be dealt with in isolation. Their solution depends upon understanding and voluntary actions by many of our people, and neither will be forthcoming in adequate degree from those who believe that government does not speak for them and does not respond to their needs."

On the other hand, it is possible that fertility rates in all segments of the population might fall to replacement rates of their own accord, without any explicit attempts to influence them. Such a development would meet the requirement of the prevailing ethical view (*19*) that primacy be given to freedom of choice in the actualization of any approach to zero population growth, and some recent evidence (*20*) would seem to suggest the possibility of such a development for the near future. However, it is still quite possible (*21*) that the fertility reduction necessary for attaining and maintaining zero population growth may not come about on a totally voluntary basis —at least, there is ample evidence (*21*, *22*) to warrant raising the question. If it should, in fact, turn out that fertility rates in some segments of the population failed to decrease to replacement levels—or, perhaps, failed to do so as rapidly as might be deemed desirable—what approaches would the society as a whole then adopt for coping with that situation?

References and Notes

1. T. Frejka, *Pop. Stud.* **22**, 379 (1968).
2. Commission on Population Growth and the American Future, *Population and the American Future* (Government Printing Office, Washington, D.C., 1972).
3. U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 480 (Government Printing Office, Washington, D.C., 1972).
4. C. V. Kiser, W. H. Grabill, A. A. Campbell, *Trends and Variations in Fertility in the United States* (Harvard Univ. Press, Cambridge, Mass., 1968); P. Demeny and P. Gingrich, *Demography* **4**, 820 (1967).
5. N. Keyfitz, *Introduction to the Mathematics of Population* (Addison-Wesley, Reading, Mass., 1968); A. J. Coale, *The Growth and Structure of Human Populations* (Princeton Univ. Press, Princeton, N.J., 1972).
6. For making the projections, the survivorship ratios corresponding to the life expectancy for each projection period are obtained from the "West" model life tables of A. J. Coale and P. Demeny, *Regional Model Life Tables and Stable Populations* (Princeton Univ. Press, Princeton, N.J., 1966), part 2, pp. 2–25.
7. The gross (G) and net (N) reproduction rates are related through the effect of mortality on survivorship to childbearing:

$$G \approx \frac{N}{p(\bar{a})}$$

since

$$G = \int m(a)\, da$$

and

$$N = \int p(a)\, m(a)\, da \approx p(\bar{a}) \int m(a)\, da$$

where $p(a)$ is the survival ratio from birth to age a, $\bar{a}$ is the mean age at childbearing, $m(a)$ is the maternity frequency at age a, and integration is over the total childbearing period. However, changes in $p(\bar{a})$ resulting from the assumed changes in life expectancy over the years are not large enough to produce a difference between the assumed trends in net reproduction rate and the resulting trends in gross reproduction rate. For making projections, the age-specific maternity frequencies for each period are based on the assumption that all future schedules will be proportional to the initial schedule. The schedule for each period is obtained by multiplying the initial schedule by a fractional constant equal in size to the ratio of the G for the period to the initial G. This assumption does not unduly distort the results of

the projections. For a fuller discussion see Frejka (*1*).
8. That is, total fertility rate (T) = 2.08. (The sex ratio at birth is set at 1050 males per 1000 females.)
9. U.S. Public Health Service, *Vital Statistics of the United States, 1968*, vol. 1, *Natality* (Government Printing Office, Washington, D.C., 1970), table 1-4, p. 1-6; U.S. Public Health Service, *Monthly Vital Statistics Report* (Government Printing Office, Washington, D.C., 1973), vol. 21, No. 12, p. 1.
10. Periods of below-replacement fertility in the 1930's were followed by various alarms about "race suicide," and governments instituted pronatalist programs to stimulate a resurgence of fertility rates. Partly in response to such programs, and also in response to more general social and economic conditions, fertility rates did in fact subsequently rise. In the ensuing years, fertility rates rose to the point of a "baby boom" in the post-World War II era, and then began to fall again in the 1960's. Concerning probable future conditions, the available evidence (*20*) suggests, with respect to a lower limit, that desires and plans for families are still widespread enough that, even if temporary postponements lower fertility rates in certain periods, in the long run there will probably continue to be enough childbearing to guarantee at least replacement fertility in the total population. With respect to an upper limit, the finite environment will simply make it necessary for population growth to balance out at zero levels in the long run. Fluctuations may of course occur in the interim, possibly following swings in general economic and social conditions [see R. Easterlin, *Nat. Bur. Econ. Res. Occ. Pap. No. 79*, (1962)].
11. Coale-Demeny (*6*, part 2, p. 72) West model stationary population, mortality level 24.
12. $\Delta = \frac{1}{2} \Sigma |p_{1i} - p_{2i}|$ where p_{1i} and p_{2i} are the entries in the two percentage distributions (i ranges over the same number of categories for both distributions; Δ may also be obtained by adding only the positive differences between the distributions, or by adding only the negative differences and then disregarding the sign).
13. The data actually show a negligible negative growth rate as the final rate because of a technical problem in model specification: the oldest age group used for the population projections was 80 and over, yet the error that results from truncating the age scale, even at this point, accumulates enough in the long run to produce the observed effect.
14. For example, see *Muhammad Speaks* (1 September 1967, p. 5; 5 January 1968, p. 24; 24 January 1969, p. 7; 31 July 1970, p. 3); *Ebony* (March 1968), p. 29; W. A. Darity, C. B. Turner, H. J. Thiebaux, *Population Reference Bureau Selection No. 37* (Population Reference Bureau, Washington, D.C., 1971).
15. Rev. J. Jackson in a discussion of the report of the Commission on Population Growth and the American Future (NET-TV, 27 November 1972).
16. Since the computation process adopted the net reproduction rate as the starting point, internal assignment of the initial life expectancy to the first projection period resulted in gross reproduction rates of 1.94 in the early period. The final, fixed rate was the initial 1.92, with a corresponding net reproduction rate of 1.89. The effect on results is negligible.
17. W. Barclay, J. Enright, R. T. Reynolds, *NACLA* [*North American Congress on Latin America*] *Newsletter* **4** (No. 8), 1 (1970); J. Jackson (*15*); see also the population commission report for alternative developments of various aspects of the "smoke-screen" argument (*2*, pp. 61, 71–74).
18. B. L. Crowe, *Science* **166**, 1103 (1969); G. Hardin, *ibid.* **162**, 1243 (1968).
19. See D. Callahan, *Science* **175**, 487 (1972); population commission (*2*); and articles by A. J. Coale (pp. 168–181), F. Notestein (pp. 31–43), and A. J. Dyck (pp. 351–377), in *The American Population Debate*, D. Callahan, Ed. (Doubleday, Garden City, N.Y., 1971).
20. U.S. Bureau of the Census, *Current Population Reports*, series P-20, No. 240 (Government Printing Office, Washington, D.C., 1972).
21. See articles by G. Hardin (pp. 259–266), K. Davis (pp. 227–258), A. J. Coale (pp. 168–181), J. Blake (pp. 298–324), M. M. Ketchel (pp. 279–297), and O. Harkavy *et al.* (pp. 325–350), in *The American Population Debate*, D. Callahan, Ed. (Doubleday, Garden City, N.Y., 1971).
22. K. E. Bauman, *Demography* **9**, 507 (1972).
23. The research reported here was supported by the Population Council. I particularly wish to thank T. Frejka for granting me free use for my own purposes of the population projection computer program that he developed. I also thank him and W. Seltzer and R. G. Potter for their comments on an earlier draft of this article.

NEWS AND COMMENT

Science in Mexico (I): The Revolution Seeks a New Ally

Mexico City. Not far from this city's great central square is a brooding hulk of a colonial building that at one time or another has been home to as wide an array of scientific endeavor as any structure in the Western Hemisphere. The first tenants of the Palacio de Minería, as the building is called, included Imperial Spain's school of mines in the 1790's. More recently, in fact up until the early 1950's, one large and rather gloomy room of the Palacio was occupied by a tiny band of half a dozen scientists, two or three technicians, and one secretary who together made up the national university's Institute of Physics. The institute, which busied itself mainly with cosmic rays, in turn constituted most of Mexican physics research.

Marcos Moshinsky, who was then a young physicist freshly graduated from Eugene Wigner's tutelage at Princeton, and has since become one of Mexico's best-known scientists, recalls that physics then was strictly a shoestring affair. Equipment tended toward the primitive, even in its time, and some of it exhibited strange idiosyncrasies. "I once made a discovery that I never published," Moshinsky says with a wry smile. "Every time a trolley car went by outside, our Geiger counters showed the cosmic ray intensity going up."

But that was 20 years ago, and physics, like most of the rest of science in Mexico, has come a long way up from the depths of poverty. If the gloom of the mining palace can be taken as a symbol of where science stood in those days, its counterpart today might be the government's new, $15 million nuclear research center at Salazar, 30 miles outside the Federal District, where university researchers have access to a reactor and a tandem Van de Graaff accelerator—both small but sophisticated—and a well-equipped collection of allied laboratories. "Salazar is certainly comparable to what we have at M.I.T. right now," notes William Buechner, a physicist at M.I.T., and a long-time acquaintance of Moshinsky's.

The institute itself has long since moved to more spacious quarters on the university's sprawling, leafy campus in the southern part of the city. And across town, physics research in the government's National Polytechnic Institute (Instituto Politécnico Nacional or IPN), the nation's second largest school, is showing signs of healthy competition.

In some ways physics has enjoyed a favored position, but its upward progress nevertheless indicates in a general way how Mexican science has fared over the past two decades. In a word, progress has been a long, slow climb punctuated in the past 2 or 3 years with a breathless gallop.

To be sure, Mexico is still a long way from plunging headfirst into big science. Pockets of poverty and serious manpower deficiencies remain; in 1972, for example, the total expenditure from all sources for R & D was only $110 million. This amount and the overall size of its science community are still small in comparison with such Latin American nations as Brazil, Argentina, and Venezuela. But even so, Mexican science is currently in the midst of a relative boom that in many ways reflects a new and positive view toward science—a view in-