THE SIGNIFICANCE OF AGE-PATTERNS OF FERTILITY IN HIGH FERTILITY POPULATIONS

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Introduction

THE study of age at marriage and age-patterns of fertility was given new impetus by the post-war "baby boom" observed in various industrialized countries in the West, where the marriage rate has been shown to be sensitive to temporal variables such as economic prosperity, and to produce "spurious" (i.e., misleading) short-term changes in the birth and reproduction rates by its fluctuations. More recently, attention is being directed, notably by Ryder,[1] to the importance of age at marriage as a factor in the demographic transition in those countries and, moreover, as a variable of possibly considerable significance in the demographic future of pre-industrial communities currently characterized by early age at marriage.

Fortuitously, in the course of our examination of differences in crude birth rates between ethnic groups in Singapore, which appeared contradictory to differentials in their gross and net reproduction rates, we were prompted to examine quantitatively the potential implications of alternative or changing age-patterns of fertility among high-fertility populations. We present our results and discussion here in the belief that they will help to clarify quantitatively the demographic significance of postponement of marriage or of childbearing, particularly in high-fertility populations.

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[1] Ryder, Norman B.: The Conceptualization of the Transition in Fertility, *Cold Spring Harbor Symposia on Quantitative Biology*, Vol. xxii, 1957. [Ryder deals more extensively and explicitly with the advantages to underdeveloped areas of later patterns of childbearing in a paper presented at the August, 1960 meetings of the American Sociological Association. The manuscript of this paper, "Nuptiality as a Variable in the Demographic Transition," was not available to us until our analysis had been completed. Having this paper in hand we now note that our work complements his by emphasizing the *quantitative effects* of variations in the age-patterns of fertility.]

Ethnic Group Differential in Singapore

The fertility indices for Malaysians and Chinese in Singapore, 1956–58, are as follows:[2]

	Malaysian	*Chinese*
Gross Reproduction Rate	3.06	3.11
Crude Birth Rate per 1,000	47.91	42.08
Child/Woman Ratio	1.05	0.90

The direction of the difference between ethnic groups in the last two indices is apparently contra-indicated by that for the gross reproduction rates. Another anomalous relation is that the Chinese population has a higher net reproductive rate—2.88 to 2.64—but a lower crude rate of natural increase—35.1 to 38.1 per thousand.

Our first reaction was that these opposite differences probably resulted from fortuitous differences in age and sex distributions. Mortality is somewhat higher among the Malaysians, but this could not account for the pattern. One other observed difference is in the age pattern of the fertility schedules of the two ethnic groups (See Fig. 1). Compared to the Chinese, the Malaysians reach peak fertility at a lower age, followed by a more rapid decline at higher ages. To evaluate the effect of this difference, we calculated *stable* (Lotka) age distributions with the two fertility schedules, combined with the life table for the Chinese female population, and found that the stable (intrinsic) female birth rates were 45.1 for the Malaysian fertility schedule and 42.1 for the Chinese. The intrinsic rates of increase were 39.7 and 36.4 per thousand respectively. Thus, the difference in the crude rates can be explained in part by the fact that younger procreation among the Malaysians produces relatively more births annually and a higher rate of population growth, even when the total number of children born during

[2] Calculated from data in Annual Reports on the Registration of Births and Deaths. Singapore, Government Printing Office; and 1957 Census of Population, Singapore. Preliminary Release No. 5. Singapore, Government Printing Office, 1959. The child/woman ratio given here is the number of children under 5 divided by the number of women aged 15–44 years.

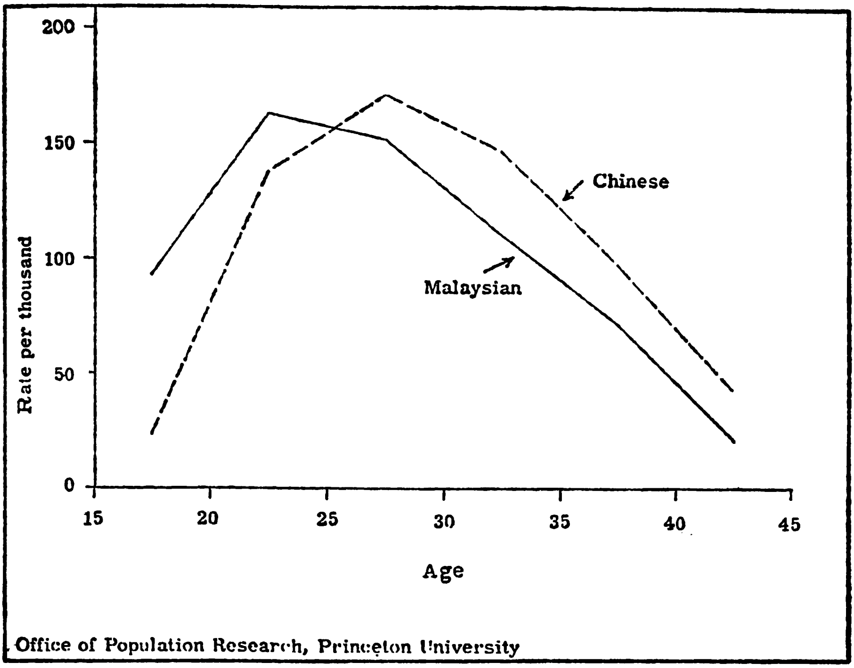

Fig. 1. Fertility schedules for Malaysians and Chinese in Singapore, 1956–1958. (Female births per thousand females.)

the childbearing span of each surviving woman is *less* than for the Chinese.[3]

The mean length of generation for the Malaysian fertility pattern is 26.4 years, and that for the Chinese 29.1. In these two populations, the 'older' pattern of childbearing is associated with a lower rate of growth equivalent to 8.3 per cent lower fertility at every age[4] in the 'younger' pattern. If the partially compensating effect of the higher fertility associated with the older pattern were removed, the difference would be equivalent to 10 per cent at every age. That is to say, if the Malaysians were to adopt the Chinese age-pattern of fertility while retaining the same gross reproduction rate, the long-run effect

[3] We have omitted consideration of errors and fortuitous variability here in order to present the argument by a simple model. The influence of level of mortality will be considered in a later section.

[4] For the method of estimating the change in fertility required to produce a given change in the intrinsic rate of growth, see A. J. Coale: The Effects of Changes in Mortality and Fertility on Age Composition, *Milbank Memorial Fund Quarterly,* January, 1956, 34: pp. 79–114.

would be identical to a reduction of 10 per cent at every age in their own age-specific fertility rates.

Re-examination of Lotka's Example

In an early statement on his stable population concepts, Lotka[5] developed a simple formula for estimating the effect on the intrinsic growth rate of postponing the "reproductive cycle" (fertility schedule) by n years. The resulting change in the intrinsic growth rate, denoted by Δr where r is the rate before the postponement, can be expressed as follows:

$$\Delta r = \frac{\log_e \frac{l_{T+n}}{l_T} - nr}{T+n} \qquad (1)$$

where $\frac{l_{T+n}}{l_T}$ is the probability of surviving from age T (the mean length of generation before the postponement) to age T + n.[6]

In Lotka's numerical example, r was 5.47 per thousand, T was 28.33 years (the values for the native white population of the United States in 1920), and n was arbitrarily taken as 5 years. The decrease in r was 1.85 per thousand, and this was equivalent to a decrease in fertility at every age by only 5.2 per cent—not a strikingly large change. This rather small magnitude of change, in spite of a postponement of 5 years, results from his choice of an example in which both mortality and fertility are low, so that both terms in the numerator of the expression in (1) above are small.

However, if fertility is high, the effect of postponement on the intrinsic rate of increase can be quite substantial because the sum of the two terms in the numerator must be large. In particular, with low mortality, r, and consequently the second

[5] Dublin, L. I. and Lotka, A. J.: On the True Rate of Natural Increase, *Journal of the American Statistical Association,* September, 1925, 151: pp. 305–39.

[6] Note that if n is positive, as in the example which Lotka offers where fertility is *postponed,* $\frac{l_{T+n}}{l_T}$ is less than 1; hence the term $\log_e \frac{l_{T+n}}{l_T}$ is *negative.* Note also that if r is negative, the effect of postponing fertility by n years can be zero, when $nr = \log_e \frac{l_{T+n}}{l_T}$.

term in the numerator, is large; whereas when r is small, with high mortality, the *first* term will be large. Thus, with the higher fertility of Singapore, a difference of only 2.7 years in the mean length of generation between the Malaysians and Chinese is equivalent to a greater difference in fertility than a postponement of 5 years in Lotka's example.

A further peculiarity in Lotka's example may be mentioned here. In reality, postponement of fertility, whether through postponement of marriage or otherwise, does not usually result in the fertility age schedule being bodily shifted along the age-axis as assumed in his example, but simply in changing the shape or skewness of the fertility schedule over essentially the same age range. Nevertheless, this in no way reduces the applicability of equation (1), but simply requires that n be replaced by ΔT, the increase in the mean length of generation brought about by the change. A necessary condition, however, is that the gross reproduction rate be identical for both fertility patterns concerned, so that the change in the intrinsic growth rate is generated by the postponement in fertility *without* any change in the total number of children born during the reproductive span of each surviving woman.

Equation (1) may therefore be re-written

$$\Delta r = \frac{\log_e \frac{l_{T+\Delta T}}{l_T} - r\Delta T}{T + \Delta T} \qquad (1a)$$

Why Age Patterns Affect Growth

The foregoing equation may be re-stated as follows to show the greater growth associated with younger fertility, i.e., writing ΔT as the number of years by which the mean length of generation is *reduced:*

$$\Delta r = \frac{\log_e \frac{l_{T+\Delta T}}{l_T} + r\Delta T}{T - \Delta T} \qquad (1b)$$

$$\cong \frac{{}_{\Delta T}q_{T-\Delta T} + r\Delta T}{T - \Delta T} \qquad (2)$$

where q is the conventional life-table notation for probability of dying.

The two essential reasons why a younger pattern of fertility produces faster growth are: a) younger childbearing permits some births to occur that otherwise would be prevented by mortality, and b) the growth per generation that is supplied by a given average number of offspring is compressed into a shorter period to produce a higher *annual* rate of growth. (The latter reason is a well known defect of the net reproduction rate viewed as a measure of reproductive performance. It is a measure of reproduction per *generation,* and the mean length of generation is not constant.) These two "reasons" correspond precisely to the two terms in the numerator of formula (2) above, the first term (${}_{\Delta T}q_{T-\Delta T}$) showing the contribution of reduced mortality, and the second ($r\Delta T$), the contribution of the reduction in mean length of generation.

An alternative approximate interpretation of this formula can be derived by considering the shape of the age distribution. When fertility is high, the stable age distribution shows a rapid decrease in the number of women as age advances through the childbearing span. Thus, younger childbearing means childbearing by a larger proportion of the female population, and we can estimate the effect by comparing the proportions at age T and $T - \Delta T$. Denoting proportion by c, we have (in the original stable age distribution):

$$\frac{c_{T-\Delta T}}{c_T} = e^{r\Delta T}\frac{l_{T-\Delta T}}{l_T} \qquad (3)$$

A k per cent difference in the proportion of women at the mean age of childbearing (approximately equal to T) is very nearly equivalent to a k per cent difference in fertility at all ages. If the proportion bearing children at every age were changed by a factor k,[7] we have

$$\Delta r = \frac{\log_e k}{T}$$

[7] Coale, A. J.: *op. cit.*

If now we let k equal to $\frac{c_{T-\Delta T}}{c_T}$ in (3) above, we get by substitution:

$$\Delta r = \frac{\log_e \frac{l_{T-\Delta T}}{l_T} + r\Delta T}{T} \qquad (4)$$

a formula identical with (1b) except that the denominator is T instead of T – ΔT. If ΔT is small the difference is trivial. For larger values of ΔT, equation (4) fails to allow for the difference in the age distribution itself resulting from the change in the fertility pattern. To a close approximation, then, the two parts in the numerator of equation (1a) or (1b) represent the mortality and growth components of the difference in proportions at age T and T – ΔT in the stable population.

If fertility is low, differences in the age-pattern of childbearing can be inconsequential or even have an effect opposite to what we have discussed. Although the mortality component always works towards faster growth associated with a shorter mean length of generation, this can be more than offset by the opposite effect of the growth component if the rate of growth is negative. Thus, in the numerator of formula (2), the first term (which is always positive) can be offset by a larger negative second term, if r is sufficiently negative; and the effect of a lower age of childbearing would then be equivalent to lower, rather than higher fertility. This is because a) with a net reproduction rate less than one, a shorter mean length of generation implies a faster annual decline because approximately the same decline occurs in a shorter time, or b) with a negative growth rate the younger age groups tend to have smaller numbers of women, and a lower age of childbearing brings fewer births.

Hutterite and Cocos Islands Fertility

To illustrate further the quantitative significance of fertility age-patterns in high fertility populations, we have taken fertility schedules from two extraordinarily prolific populations—on the one hand the women of the Cocos Islands (GRR = 4.17), and on the other the Hutterite women of western North America (GRR = 4.00).[8] The Cocos Islanders are characterized by especially early marriage and frequent pre-marital conceptions, while the Hutterite women marry only infrequently before the age of 20 and have almost no pre-marital conceptions. There is a difference of about 3.5 years between their mean lengths of generation.

In order to isolate the effect of the difference between the age patterns, we multiplied the Cocos Islands' age-specific fertility rates by 4.00/4.17 so that both fertility schedules had the same gross reproduction rate of 4.00. The two schedules were then combined with each of three widely different mortality conditions by using life tables with expectation of life at birth of 20, 50 and 70 years respectively. The increase in $\dot{r}$ and the equivalent increase in fertility resulting from the subsitution of the Cocos Islands' fertility patterns for the Hutterite pattern are shown in Table 1.

The effect of the difference between the fertility age-patterns is greater the more favorable the mortality conditions. With an expectation of life of 70 years, we find that the earlier fertility of the Cocos Islanders would produce an intrinsic

Table 1. Stable population indices with Hutterite and Cocos Islands fertility schedules and various life tables.

Life Table $\mathring{e}_0$	T: Hutterite Schedule	T: Cocos Islands Schedule	ΔT	$\Delta T^q T - \Delta T$	r × 1,000: Hutterite Schedule	r × 1,000: Cocos Islands Schedule	Δr	Per Cent Difference* in Effective Fertility
20	31.14	27.55	3.59	.0901	5.4	9.1	3.7	12.2
50	31.42	27.89	3.53	.0225	33.5	38.6	5.1	17.4
70	31.48	27.77	3.71	.0042	42.4	48.1	5.7	19.6

* Per cent increase in Hutterite fertility required to produce the r associated with the Cocos Islands fertility schedule. (See footnote (4) on page 633).

[8] Smith, T. E.: The Cocos-Keeling Islands: A Demographic Laboratory. *Population Studies*. November, 1960, 2: pp. 94–130. Eaton, J. W. and Mayer, A. J.: The Social Biology of Very High Fertility Among The Hutterites. *Human Biology*. September, 1953, 3: pp. 206–264.

growth rate of 48.1 per thousand, compared to 42.4 for the later fertility of the Hutterites. It would require some 20 per cent higher fertility in the Hutterite age-pattern to produce this increase of nearly 6 per thousand in the growth rate.

The outcome of these calculations can be stated in the following terms: the Hutterite population would need a gross reproduction rate of 4.49 if $\mathring{e}_0$ were 20 years, a rate of 4.70 if $\mathring{e}_0$ were 50 years, and a rate of 4.78 if $\mathring{e}_0$ were 70 years, to reproduce as rapidly as the Cocos Islanders with a rate of 4.00.

Additional Transitory Effect of Change in Age-pattern

The long-run effect of a change in the age-pattern of fertility on population growth has been evaluated above by comparing stable (intrinsic) rates produced by simulated 'initial' and 'terminal' fertility age-patterns, holding total fertility constant. In addition to this long-run effect, there is an important transitory effect produced by the 'piling up' or 'thinning out' of births that occurs when the age-pattern of fertility changes.[9] To isolate this effect, consider a hypothetical increase in average age of childbearing in successive cohorts of women such that all cohorts have a net reproduction rate of unity. Assume that mortality at ages near the mean age of childbearing is negligible. Since the population is not growing, the increase in length of generation would neither accelerate nor decelerate growth, and the long-run consequences would be nil. Yet when the *change* from the younger to the older pattern of childbearing is taking place, there would be a substantial decline in the birth rate. This birth rate would recover after a period of transition, but there would be no tendency to 'make up' for the 'lost' births unless the mean age of childbearing were to be restored to the original lower value.

The number of births lost can best be visualized by imagining

[9] The 'spurious' fluctuations in total fertility and birth rates resulting from short-term changes in cohort mean age of childbearing have been analyzed in great detail by Whelpton, Ryder and others, in relation to inter-war and post-war experiences in some Western countries. We feel, however, that there is a need for a comparatively simple explanation here, to facilitate interpretation of our population projection which follows.

that all births occur *at* the average age of childbearing of each cohort. Suppose that the cohort reaching age 25 this year produces all of its births (just enough for replacement) during this year, while the next cohort (now aged 24) waits until age 30 to produce its births. During the next five years there would be *no births at all,* and the total immediate loss (not counting second generation effects which contribute further losses, i.e. births not occuring to the children not born) will be the births that would normally have occurred in five years —the period corresponding to the increase in average age of childbearing.

With births dispersed through a wider range of childbearing ages rather than concentrated at one age, an increase of 5 years in the mean age of childbearing produces the same total loss, but spread over a longer period of time.

This transitional 'loss' in births is in addition to any long-run decline caused by a shift to later childbearing, and the combined effect is illustrated in a population projection which follows.

A Hypothetical Fertility Age-shift Applied to India

The following projection shows how the growth in the female population of India, as estimated by Coale and Hoover,[10] would be affected if the Indian fertility pattern were to shift to the older pattern of the Singapore Chinese during the 10 year period beginning in 1956. We have assumed that the female cohort aged 15–19 in 1956 experiences the age-specific fertility rates used in the Coale-Hoover projection, following which each subsequent cohort progresses 10 per cent annually towards the age-specific rates in the other schedule. Thus the cohort aged 15–19 in 1966—and all subsequent cohorts—will experience the new fertility pattern. Table 2 shows the assumed evolution of age-specific rates. All cohorts have the same gross reproduction rate of 2.64, but the *period* GRR shows a transi-

[10] Coale, A. J. and Hoover, E. M.: Population Growth and Economic Development in Low-Income Countries. Princeton University Press, 1958, p. 352.

Age	Age-specific Female Fertility Rates (per 1,000 Women) in							
	1956	1961	1966	1971	1976	1981	1986	1991
15–19	92	56	19	19	19	19	19	19
20–24	130	130	124	118	118	118	118	118
25–29	121	121	121	133	145	145	145	145
30–34	91	91	91	91	108	124	124	124
35–39	67	67	67	67	67	75	83	83
40–44	26	26	26	26	26	26	32	37
GRR	2.64	2.45	2.24	2.27	2.42	2.54	2.61	2.64

Table 2. Age-specific female fertility rates resulting from a shift from the fertility pattern estimated for India, 1956, to that of the Chinese in Singapore in 1956–58 adjusted to the same Gross Reproduction Rate. (All cohorts through that aged 15–19 in 1956 have the Indian pattern; all cohorts from that aged 15–19 in 1966 have the Singapore pattern; and intervening cohorts exhibit a linear change.)

tory fall, reaching a minimum of 2.24 in 1966, a decline of 15 per cent.

In Figs. 2 and 3, the birth rates and total population (females) resulting from this projection are compared with the Coale-Hoover projection assuming no change in fertility, and with another projection assuming a 20 per cent linear decline between 1956 and 1966.[11]

Note that the fertility age-shift produces a transitional effect in the first ten years similar to a fertility decline of 20 per cent occurring linearly in the same period. Even for 20 years, the cumulative saving in births is not much less than that achieved by a 20 per cent decrease in fertility, as shown in Fig. 4. This effect is more pronounced than the change of 15 per cent in the period GRR would suggest, and is explained by the fact that the fall in the GRR (see Table 2) is due not to a fertility decline distributed over the whole range of reproductive age but to a disproportionate decline in the younger age groups (the cohorts in the ages 15 to 24) where the effect on total period fertility is greatest.

It would be appropriate here to emphasize that the birth and growth rates do *not* eventually return to the levels where they

[11] The mortality assumptions are identical for all three projections.

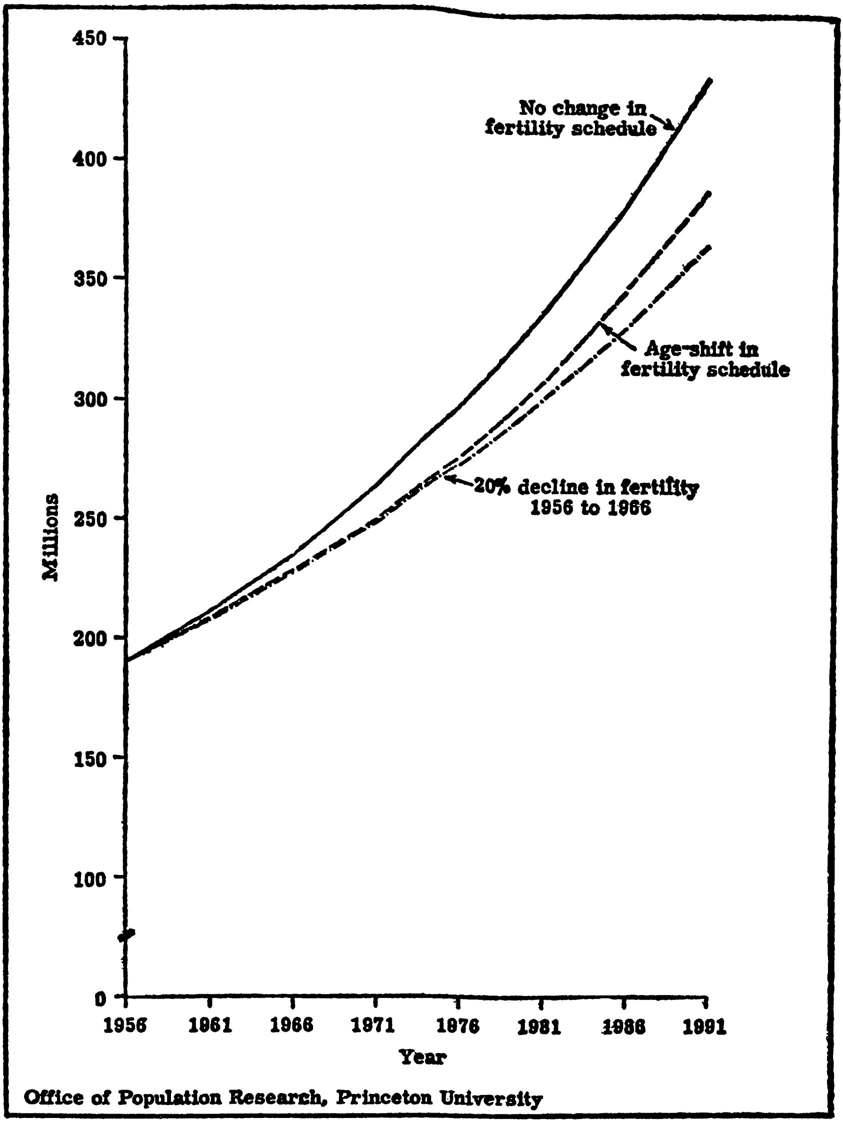

Fig. 2. Projected female population (millions) of India, 1956–1991, with various fertility assumptions.

would have been without the fertility postponement, even though the period GRR regains its initial level when the change to the new fertility age-pattern is completed. The long-run effect can be shown by applying stable population analysis, as before, to the 'initial' and 'terminal' fertility age-

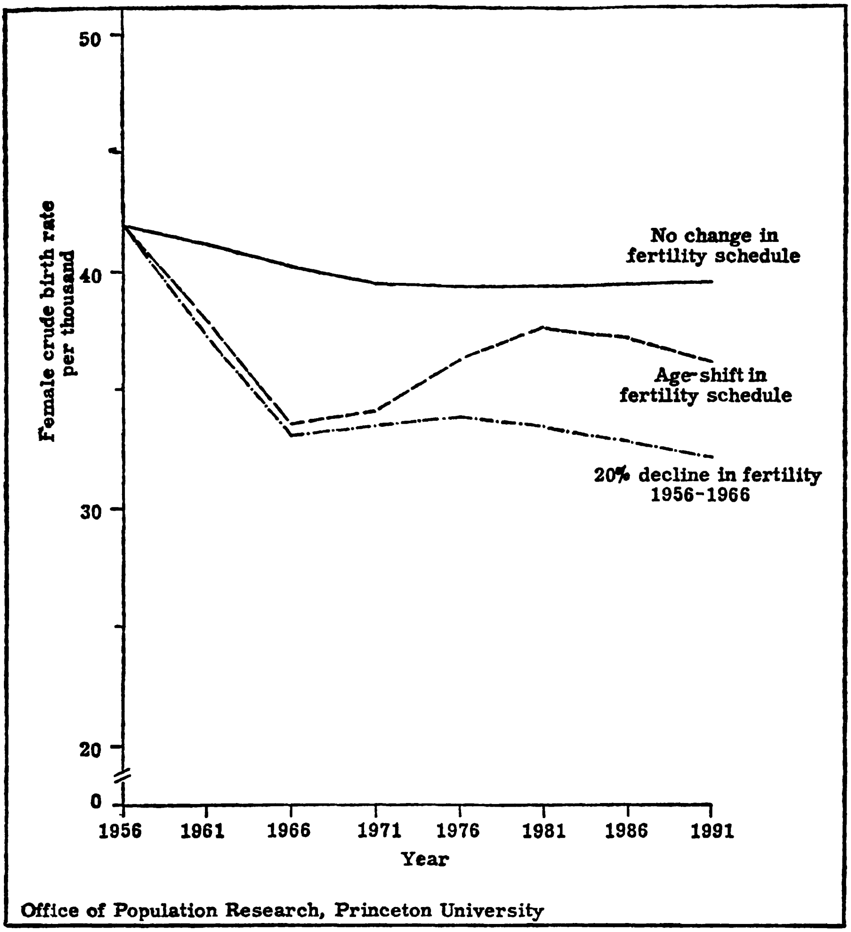

Fig. 3. Projected female crude birth rates with various fertility assumptions, India, 1956–1991.

patterns involved, and the results are shown in Table 3. Note that the increase of 2.7 years in the mean length of generation is associated with a reduction of 3.1 per thousands in the intrinsic rate of growth, which is equivalent to about 8 per cent lower fertility without the change in age-pattern.

Implications for Countries with High Fertility and Early Marriage

We have shown that the difference in effective fertility (population growth) between populations with early childbearing

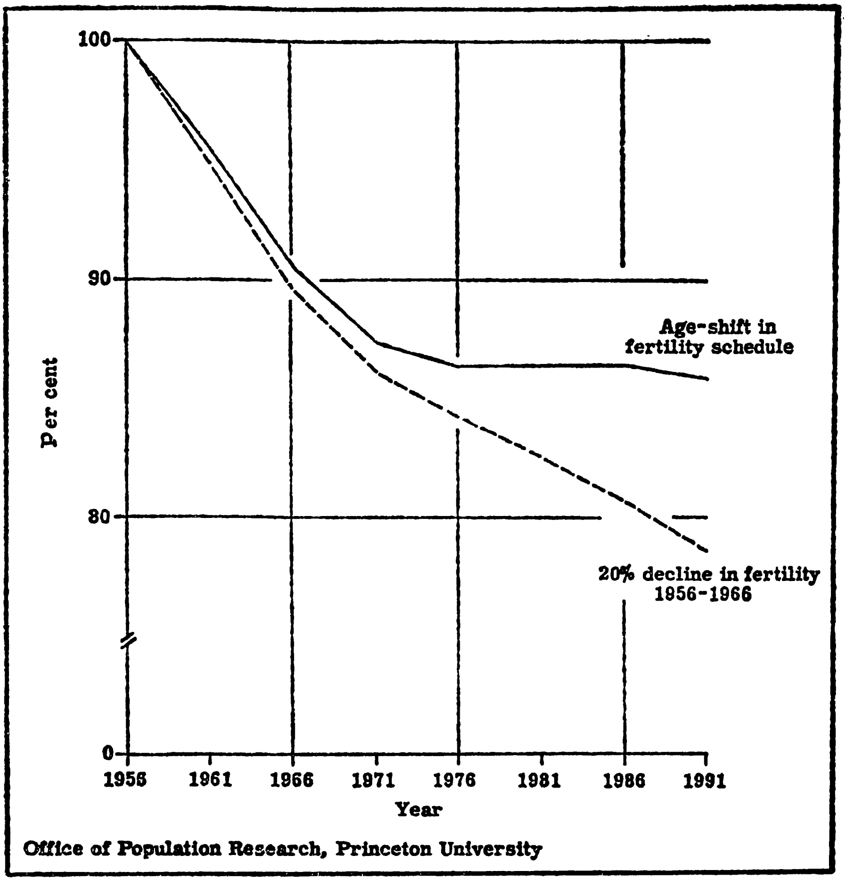

Fig. 4. Cummulative projected births from 1956, India, 1956–1991. No change in fertility = 100.

and late childbearing is of surprisingly large magnitude when fertility rates are high. In countries where contraceptive practices are virtually absent or comparatively ineffective, differ-

Table 3. Stable population indices with the fertility schedules before and after the age-shift assumed in the projection (using the life table estimated for India in 1981–5).

Fertility Pattern	T	r(× 1,000)	Per Cent of Change in Fertility to Produce Other "r"
Indian (1956)	26.34	27.21	−7.9
Singapore Chinese (1956–8)	29.03	24.10	9.5

ences in age at childbearing result principally from differences in age at marriage, and the effects of postponement of childbearing can be interpreted, therefore, as the effects of postponement of marriage.

The relation between age at marriage and completed size of family has been studied by many demographers, but no consistent relationship has been demonstrated. Some studies indicate that later marriage is associated with smaller numbers of children ever born, in non-contraceptive populations, but one cannot tell whether early marriage *causes* a more fertile union, or whether 'intrinsically' more fertile couples tend to marry earlier. On the other hand, it is possible that the fecundity of some very young brides is impaired by premature cohabitation and pregnancy, so that the postponement of very early marriages could *increase* completed size of family. Uncertainty on this score has, we believe, inhibited serious or adequate consideration of the long-term effects of postponing marriage, and certainly diverted attention from the evaluation of such effects independently of completed family size.

Our objective, in the preceding calculations, has been to show that postponement of marriage can contribute substantially to reduction in birth rates and population growth[12] even when completed size of family is *not* reduced, and that this contribution is potentially greatest in those countries which have the highest fertility and low average age of marriage. In so far as the average size of family is also more likely to fall than to remain unaffected by later marriage, this contribution is likely to be even greater than our models would suggest.

We do not, however, profess to know exactly how postponement of marriage can best be accomplished—this clearly depends on the circumstances in each country—nor to know how much postponement in marriage is required to produce a given increase in the value of T, the mean length of generation. Nevertheless, our calculations suggest that postponement must

[12] Although the analysis has been confined to females, the interpretation can clearly be extended to both sexes since the sex ratio of births is relatively constant.

be given serious consideration as a powerful supplementary component of population policy in the crucial decades ahead. Postponement would provide a substantial and immediate transitory reduction in the birth rates as well as a smaller permanent decline, and these would be in addition to, and perhaps even help to promote, further decline ultimately achieved through more prevalent and effective practice of contraception.[13]

Other Implications of the Age-pattern of Childbearing

Many demographers have viewed with skepticism reports of birth rates of 60 or more estimated from sample records for some parts of Africa. With young childbearing, these rates are not as improbable as was once thought. The Cocos Islanders, for example, would have a stable birth rate of 61 per thousand if their expectation of life at birth were 20 years and their fertility 4 per cent less than it is. With the older childbearing of the Hutterites, on the other hand, the birth rate would not exceed 56 with comparable high fertility, no matter what the mortality level is.

The magnitude of the influence of age on effective fertility also emphasizes the limitations of some conventional fertility indices for comparative purposes. For example, total fertility rates, gross and net reproduction rates, and data on completed size of family are measures of fertility only when fertility is viewed as the average life-time performance of cohorts (real or synthetic) of women. A higher gross reproduction rate means more children born during a life-time, but this cannot be considered as an indication of *reproductive* performance in a population (not even gross of mortality) unless the mean age of childbearing is taken into account. The reason for this is clear from the examples given earlier.

[13] Ryder, N. B.: *op cit.* Ryder has argued persuasively that postponement of marriage would have a powerful tendency to offset the social forces that sustain marital fertility at a high level, in addition to the timing effects that we have emphasized.