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Reduction in population growth under different contraceptive Policies

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Abstract. A number of equations for the various population control policies are worked out for a desired reduction in the rate of growth. At the ages of 25 and 30 respectively, 61 and 97% of contraceptive users are necessary to reduce the present rate of growth of 0·026 to 0·010. While at the age of 25 about 69 and 76% contraceptive users are required for the same reduction in the rate of growth, assuming that 25 and 50% would discontinue the use of contraceptives at the age of 35. The birth and death rates in the study area (Varanasi Rural) have remained almost constant for several years, justifying the assumption of a stable population. This study emphasises the need for the use of contraceptive devices at two or more age levels.

Keywords. Child bearing; contraceptive devices; reproductive value; stability; population growth.

Introduction

In spite of the target oriented and the time-bound family planning programme in India, there has been a considerable delay in the demographic goal of achieving a birth rate of 25 per thousand population. The target date of 1963 was revised several times and is now at 1984. Each time the decilineal goal has been planned without any scientific and/or empirical evidence. Srinivasan (1977) has rightly pointed out that "the gaps between the target fixed and the achievement in the earlier five year plan periods may be due to the defects in the implementation of the programme by the government or due to defects in the setting up of the targets for various methods of family planning or due to defects in the assumptions relating to the possibilities of achieving desired national targets within specified period of time".

Statistically-simulated models, framed within the limits of specific conditions (Scenerios) and assumptions can usefully project the programme targets and achievements (Potter and Parker, 1964; Singh, 1964; Yadava, 1977). A rigorous theoretical analysis of the effects of sterilisation/emigration on the population growth has been given by Keyfitz (1971, 1975). Keyfitz's results are the starting point for any in-depth study of the relationships between population growth and contraceptive devices. Keyfitz (1975) has derived several expressions to obtain the proportion of sterilisations/emigrations at certain age level to achieve the desired rate of population growth taking base line population to be stable (a population that is governed by a regime of unchanging fertility and mortality schedules for a long time with no migration).

Based on the national target for the desired population growth, some expressions regarding contraceptive policies are worked out according to Keyfitz (1971, 1975) in order to find out the proportions of contraceptive users at different age levels. Two types of contraceptive policies are proposed in this paper and the consequences of these policies on population growth have been evaluated.

Contraceptive policies

Proportions of contraceptive users under different policies to obtain the desired rate of growth

It was observed that sterilisation or any other contraceptive device will have no effect on the immediate rate of growth and its ultimate effect depends on the cautious use of this policy (Keyfitz, 1975). A continued stream of users, at a given age or at some ages, can be thought of as either reducing age specific fertility or creating a discrete drop in the survivor function. The rate of growth, r, is determined by fertility and mortality schedules alone and it is the only real root of Lotka's integral equation,

$$\int_{\alpha}^{\beta} \exp(-ra)\, p(a)\, m(a)\, da = 1, \tag{1}$$

where $p(a)$ is the fraction of the females in the population that survives to age a, $m(a)\,da$ is the probability that a female who is of age a will bear a female child in the next da period of her life and α and β are the lower and upper limits of the reproductive period respectively.

If the present rate of growth r has to be reduced to a desired rate of growth r^*, then the proportions of contraceptive users under following policies are:

Policy–I : A continued stream of contraceptive users at a single age level x for $x < \beta$.

Policy–II : A certain proportion of the population uses a contraceptive device at a certain age level x and a certain proportion of the users discontinue on reaching age y ($x < y < \beta$).

Policy–Ill : A continued stream of contraceptive users at two age levels x and y.

Expressions for the proportions of users under these policies are derived in. Appendix 1 and are presented by equations (A.1.2), (A.1.6) and (A.1.9), respectively.

Reduction in the rate of growth for a given proportion of users

The reduction in the rate of growth r are evaluated under the following policies:

Policy–IV : A certain proportion f of the population uses a contraceptive method continuously after reaching age x ($x < \beta$) and a certain proportions σ of the remaining population uses at age y ($y > x$). The remaining population uses at age z ($z > y > x$).

Policy–V : In addition to policy–IV, the age at marriage is increased to m for $m > \alpha$.

Under policies IV and V, expressions for the reduction in the rate of growth, r, are derived in Appendix 1 and are presented by equations (A.1.12) and (A.1.13) respectively.

Illustration

The different population control policies described above are illustrated with the help of the data collected in the Demographic Survey of Rural Varanasi 1969–70, henceforth known as the Varanasi Survey 1969–70. The details of the survey are given by Singh *et al.* (1970).

To illustrate the different policies as proposed under contraceptive policies mentioned earlier, the values of net maternity function $p(a)\ m(a)$ are required. The values of $m(a)$ are computed with the help of the data collected in the Varanasi Survey 1969–70. The computational procedures are given in Appendix 3 to this paper. The values of $p(a)$ are taken from the regional Model Life Table of Coale and Demeny (1966) (South; level, 13). This level has been chosen due to the similarity in mortality experience of the region under study. The value of the rate of growth r and the other population parameters are computed with the help of data collected in the Varanasi Survey 1969–70. The computational procedures are given in Appendix 2. Table 1 presents the values of $p(a)\ m(a)$, the net maternity function; R_0, the net reproduction rate; μ, the mean length of generation time along with other population parameters.

Table 1. Values of net maternity function $p(a)\ m(a)$ along with R_0, μ, r and the calculation of exp $(-r^*a)\ p(a)\ m(a)$ for estimating the proportion of contraceptive users to achieve the rate of growth $r^* = 0{\cdot}010$ from $r = 0{\cdot}026$.

Age (z)	$p(a)$	$p(a)\ m(a)$	$\exp[-0{\cdot}010\ (z+2{\cdot}5)]\ {}_5P_zF_z$	$\int_z^\beta \exp(-r^*a)\ p(a)\ m(a)\ da$
10	0·76519	0·007435	0·006560	1·63099
15	0·75517	0·226100	0·18980	1·62444
20	0·74104	0·501910	0·40078	1·43464
25	0·72334	0·507236	0·38528	1·03385
30	0·70420	0·463757	0·33511	0·64857
35	0·68450	0·295786	0·20329	0·31346
40	0·66350	0·144068	0·09419	0·11017
45	0·64092	0·025689	0·01598	0·01598

$R_0 = 2{\cdot}172$; $\mu = 28{\cdot}91$; $y = 0{\cdot}026$.

Example: The proportion of females proposed for contraceptive usage at age 25 to bring the present rate of growth 0·026 to 0·010 is

$$\frac{1{\cdot}63099 - 1}{1{\cdot}03305} = 0{\cdot}61033.$$

If we assume a death rate of about 15 per thousand population upto 1984 and the birth rate of 25 per thousand population (approximately, the national target), the rate of growth would be 0·010. The values of exp $(-r^* a)\, p(a)\, m(a)$ for $r^* = 0{\cdot}01$ are calculated in table 1. By using the equation (A.1.2) for policy–I and the data (table 1), it is found that at age 25 about 61% contraceptive users are required to bring down the rate of increase from 0·016 (present rate of increase) to 0·010. Similarly at age 30 about 97% contraceptive users are required for the same reduction in the rate of growth.

If we take $x = 25$, $y = 35$ and $\sigma = 0{\cdot}5$, then from equation (A.1.6) for policy–II, it can be shown that about 76% of the females at 25 years of age should adopt contraceptive devices in order to have the rate of growth from 0·026 to 0·010 assuming that 50% of the users would discontinue at the age of 35 years. In the case $x = 25$, $y = 35$ and $\sigma = 0{\cdot}25$, about 69% of females are required to adopt contraceptive methods at the age of 30 years to get a rate of growth of 0·01.

Under policy–III, if $x = 25$, $y = 30$ and $f_2 = 0{\cdot}5$, then from equation (A.1.9) it is found that about 43% of females are needed to use a contraceptive method at the age of 25 years to get a rate of growth of 0·01 assuming that 50% of the remaining females would adopt contraceptive policies at the age of 30 years.

To illustrate the policies IV and V, the values of f, σ, x, y and z are required. For the sake of convenience, the values of x, y and z are taken, approximately as the ages of 3rd, 4th and 5th parities, respectively. For the Varanasi Survey 1969–70, it is computed that average age of females at 3rd, 4th and 5th parities are about 26, 29 and 32 years respectively and hence, the values of x, y and z may be taken as 26, 29 and 32, respectively.

Taking $x = 26$, $y = 29$, $z = 32$ and $f = \sigma = 0{\cdot}5$ in equation (A.1.12), then under policy–IV, we have the value of Δ_r, the reduction in r as

$$\Delta_r \simeq 0{\cdot}0025 \text{ with } R_o = 1{\cdot}06,$$

and from fertility schedule (A.1.13) with $f = \sigma = 0{\cdot}5$, $x = 29$, $y = 32$, $z = 35$ and $m = 20$, we get

$$\Delta_r \simeq 0{\cdot}0038 \text{ with } R_0 = 1{\cdot}12.$$

It is, however, interesting to observe that reduction in the rate of growth through policy–V expressed by quation (A.1.13) is slightly more than that of policy–IV expressed by equation (A.1.12). This may be due to the fact that fertility between the ages 15 to 20 years is lower than that between 32 to 35 years.

References

Coale, A. J. (1972) *The growth and structure of human populations : A mathematical investigation* (Princeton : University Press).

Coale, A. J. and Demeny, P. (1966) *Regional model life tables and stable population* (Princeton : University Press).

Keyfitz, N. (1971) *Popul. Stud.* (*London*), **25,** 63.

Keyfitz, N. (1975) *Reproductive value : with applications to migration, contraception and zero population growth, Quantitative sociology*, (San Francisco, London : Academic Press), ρ 587.

Lotka, A. J (1939) *Theorie analytique des associations biologiques. II, Analyse demographique application particuliere a l' espece Lumainec actualites scientifiques at industrielles.* (Paris : Hermann), p. 780.

Potter, R. G. and Parker, M. P. (1964) *Popul. Stud.* (*London*), **18,** 99.
Singh, S. N. (1964) *Sankhya*, **B26,** 95.
Singh, S. N., Yadava, R. C. and Bhaduri, T. (1970) *Prajna*, **16,** 176.
Srinivasan, K. (1977) *India population project Newsletter*, 3.
Yadava, K. N. S. (1977) *Some aspects of out-migration and its effect on fertility,* Ph.D. thesis, Banaras Hindu University, Varanasi.

Appendix 1

Keyfitz (1971) has shown that when a proportion f of the population uses any contraceptive method on reaching age x, ($x < \beta$ and $0 \leq f \leq$) the new rate of growth r^* satisfies

$$\int_\alpha^\beta \exp(-r^* a)\, p(a)\, m^*(a)\, da = 1, \tag{A.1.1}$$

$$\text{with} \quad m^*(a) = \begin{cases} m(a) & \text{if } a < x \\ (1-f)\, m(a) & \text{if } a \geq x. \end{cases}$$

Solving (A.1.1) for f,

$$f = \frac{\int_\alpha^\beta \exp(-r^* a)\, p(a)\, m(a)\, da - 1}{\int_x^\beta \exp(-r^* a)\, p(a)\, m(a)\, da}\,. \tag{A.1.2}$$

Equation (A.1.2) can be used to find the amount of females at age x that would be required to use the contraceptive method (under policy–I) for the desired rate of growth r^*. In order to achieve a stationary population, i.e., $r^* = 0$, equation (A.1.2) reduces to

$$f = \frac{R_0 - 1}{\int_x^\beta p(a)\, m(a)\, da} \tag{A.1.3}$$

Where $R_0 = \int_\alpha^\beta p(a)\, m(a)\, da$ is the net reproduction rate.

Under policy–II, i.e., in the case of contraceptive devices like I.U.C.D., oral pills, etc., if a certain proportion of f ($0 \leq f \leq 1$) of the population uses on reaching age x and a certain proportion σ ($\sigma < f$) f discontinues on reaching age y ($x < y < \beta$), then the new rate of growth, r^* satisfies

$$\int_\alpha^\beta \exp(-r^* a)\, p(a)\, m^{**}(a)\, da = 1, \tag{A.1.4}$$

$$\text{with} \quad m^{**}(a) = \begin{cases} m(a) & \text{if } a < x \\ (1-f)\, m(a) & \text{if } x \leqslant a < y \\ (1-f+\sigma)\, m(a) & \text{if } a \geqslant y. \end{cases} \tag{A.1.5}$$

solving (A.1.4) for f,

$$f = \frac{\int_\alpha^\beta \exp(-r^* a)\, p(a)\, m(a)\, da + \sigma \int_y^\beta \exp(-r^* a)\, p(a)\, m(a)\, da - 1}{\int_x^\beta \exp(-r^* a)\, p(a)\, m(a)\, da}. \tag{A.1.6}$$

Thus for a known value of σ (discontinuation rate), the value off can be computed for the desired reduction in the rate of growth.

Under policy–III, if there are a, continued stream of users at two ages, x and y, then the new rate of growth r^* satisfies

$$\int_{\alpha}^{\beta} \exp(-r^* a)\, p(a)\, \bar{m}(a)\, da = 1, \tag{A.1.7}$$

$$\text{with} \quad \bar{m}(a) = \begin{cases} m(a) & \text{if } a < x \\ (1 - f_1)\, m(a) & \text{if } x \leqslant a < y \\ (1 - f_2)(1 - f_1)\, m(a) & \text{if } a \geqslant y, \end{cases} \tag{A.1.8}$$

where f_1 and f_2 are the proportions of users at ages x and y respectively. From (A.1.7) and (A.1.8) we have,

$$f_1 = \frac{\int_{\alpha}^{\beta} \exp(-r^* a)\, p(a)\, m(a)\, da - f_2 \int_{y}^{\beta} \exp(-r^* a)\, p(a)\, m(a)\, da - 1}{\int_{x}^{\beta} \exp(-r^* a)\, p(a)\, m(a)\, da - f_2 \int_{y}^{\beta} \exp(-r^* a)\, p(a)\, m(a)\, da} \tag{A.1.9}$$

For a, given r^* and f_2, f_1 can be estimated with equation (A.1.9). A similar expression for f_2 in terms of f_1 and r^* can be worked out.

Under policy–IV, when a proportion f of the population uses any contraceptive method continuously on reaching age x and a, proportion σ of the remaining population uses at age y ($y > x$) and the remaining population uses at the age z ($z > y > x$), the new rate of growth, r' satisfies

$$\int_{\alpha}^{\beta} \exp(-r' a)\, p(a)\, m'(a)\, da = 1, \tag{A.1.10}$$

$$\text{with} \quad m'(a) = \begin{cases} m(a) & \text{if } a < x \\ (1 - f)\, m(a) & \text{if } x \leqslant a < y \\ (1 - \sigma)(1 - f)\, m(a) & \text{if } y \leqslant a \leqslant z \\ 0 & \text{if } a \geqslant z, \end{cases} \tag{A.1.11}$$

where $r' = r + r\,\Delta_{r'}$;

Δ_r is the amount of reduction in the rate of increase r. If Δ_r is small enough that

$$\exp - (\Delta_r)_a \simeq 1 - (\Delta_r)_a,$$

and also if f and σ are small enough that $(f\ \Delta_r)$ and $(1 - f)$. Δ_r are neglected, the expression for Δ_r comes to

$$\Delta_r \simeq \frac{\int_{x}^{z} \exp(-ra)\, p(a)\, m(a)\, da + \sigma(1 - f) \int_{y}^{z} \exp(-ra)\, p(a)\, m(a)\, da - \exp(-ra)\, p(a)\, m(a)\, da}{\int_{\alpha}^{z} a \exp(-ra)\, p(a)\, m(a)\, da}. \tag{A.1.12}$$

For $\sigma = 0$ and $z \geq \beta$, the equation (A.1.12) reduces to that of Keyfitz (1975).

It has been suggested that the increase in the age at marriage may be considered as a method of controlling the growth of population. If the age at marriage is increased to m years for $m > a$, the schedule of fertility, $m''(a)$ along with the schedule (A. 1.11) , takes the new form as

$$m''(a) = \begin{cases} 0 & \text{if } a < m \\ m(a) & \text{if } m \leqslant a < x \\ (1-f)\, m(a) & \text{if } x \leqslant a < y \\ (1-\sigma)(1-f)\, m(a) & \text{if } y \leqslant a < z \\ 0 & \text{if } a \geqslant z. \end{cases} \tag{A.1.13}$$

The value of ∇_r can be obtained under policy-V with the fertility schedule (A.1.13).

Appendix 2

Computational procedures

The values of integrals in the 5-yearly age intervals are approximated by Coale (1972) to be

$$\int_z^{z+4} \exp(-ra)\, p(a)\, m(a)\, da = \exp[-r(z+2.5)]\ {}_5p_z F_z, \tag{A.2.1}$$

where $5P_z = \int_z^{z+4} p(a)\, da$; and F_z is the age specific fertility rate for females aged z to $z + 4$ at last birthday.

The rate of increase r is computed by using the standard formula of stable population (Coale, 1972) as

$$r \simeq \log R_0/T, \tag{A. 2.2.}$$

where T is the mean length of generation in the stable population and $T \simeq \mu$, where μ is the mean generation time.

Appendix 3

Computation of age-specific fertility rates

Age-specific fertility rates, defined as the average number of children born in a year to a woman of given age, have been computed using data on number of children born to women of different age-groups.

Firstly, women are classified according to their present age, into five-year age-groups. The average number of children born to those women in the successive age-groups is computed and plotted against the age. The number of children born at the end periods of the age-intervals are interpolated and by successive differences, the average number of children born during the intervals is computed and a division by five gives the age-specific fertility rate (ASFR).

Computation of m (a)

Since the computation of ASFR included all the women, this does not take into account whether she is eligible or not. Thus, multiplying these ASFR by the proportion of eligible women of the particular age-group, the ASFR can be computed. Further, multiplying by sex-ratio and 5 (due to 5 yearly age-group), the values of $m(a)$, *i.e.*,

$$m(a) = \text{ASFR} \times S(a) \times Q \times 5$$

Table 2. The values of age-specific fertility rates (ASFR) and $S(a)$ for each age-group.

Age-group	ASFR	$S(a)$
10–14	0·050	0·07980
15–19	0·170	0·72328
20–24	0·290	0·95915
25–29	0·305	0·94421
30–34	0·275	0·98356
35–39	0·205	0·86567
40–44	0·105	0·84926
45–49	0·020	0·82305
Total	1·420	

can be obtained where Q is the sex-ratio at birth and $S(a)$ is the proportion of eligible couples. The value of Q in the Varanasi Survey 1969–70, is 0·487 female birth/per birth and the values of $S(a)$ along with ASFR are presented in table 2 to appendix 3.