

# Reduction in Population Growth under Various Contraceptive Strategies in Uttar Pradesh, India

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**Abstract**—Contraceptive policies have been derived to achieve desired reductions in the growth rate and also, applied to the data of Uttar-Pradesh, India for illustration. Using the Lotka's integral equation for the stable population, expressions for the proportion of contraceptive users at different ages have been obtained. At the age of 20 years, 42% of contraceptive users is imperative to reduce the present annual growth rate of 0.036 to 0.02, assuming that 40% of the contraceptive users discontinue at the age of 25 years and 30% again continue contraceptive use at age 30 years. Further, presuming that 75% of women start using contraceptives at the age of 23 years, and 50% of the remaining women start using contraceptives at the age of 28 years, while the rest of them start using it at the age of 32 years. If we set a minimum age of marriage as 20 years, a reduction of 0.019 in growth rate will be obtained. This study describes how the level of contraceptive use at different age groups of women reduces the growth rate in the state of Uttar Pradesh. The article also promotes delayed marriage in the region.

**Keywords**—Child bearing, contraceptive devices, contraceptive policies, population growth, stable population.

## I. INTRODUCTION

POPULATION growth in India has always been an issue of attention among researchers and policymakers for decades. India, a country situated in south Asia, is the second most populous country on earth, with 16.7% of the planet's inhabitants. Population growth in India has always been an issue of attention among researchers and policymakers for decades. In 2005, [1] addressed the issues of religious differentials in population growth in India and contraceptive practices. As per the vision of [2], a target Total Fertility Rate (TFR) of 2.1 was set to be obtained by 2010. In spite of the obvious decline in TFR from 3.6 in 1991 to 2.4 in 2012 [3], India is yet to achieve the replacement level of 2.1. More than 20 states/ union territories of India have already reached the replacement level of TFR by 2012, while Uttar Pradesh with the largest population still has TFR of 3.3 [3]. Uttar Pradesh accommodating approximately 204 million people, has a higher level of fertility and contributes significantly to the population growth of India. Due to the above fact, several works have been done regarding the population growth, fertility transition, and contraceptive behaviors by many researchers [4]-[6]. According to [7], "The gaps between the target fixed and the accomplishment in the earlier five-year plan terms may be due to the deficiencies in the implementation of the plan by the government or due to flaws in the setting up of the targets for several methods of family

planning or due to errors in the assumptions relating to the possibilities of achieving desired national goals within specified period of time".

Statistical models, framed within the limits of specific scenarios and assumptions can usefully project the program objectives and achievements [8], [9]. A precise theoretical analysis of the effects of sterilizations/ emigrations on the population growth has been given by [10], [11]. Keyfitz's results are the origin point for any extensive study of the relationships between population growth and contraceptive devices. Reference [10] has derived several expressions to obtain the proportion of sterilizations/ emigrations at particular age levels to accomplish the desired rate of population growth taking baseline population to be stable. As well, [10], [11] have derived some expressions regarding the contraceptive policies to investigate the proportions of contraceptive users at different age levels, based on the desired population growth.

Reference [12] proposed two types of contraceptive policies. The first type of policies attempt to determine the required proportions of contraceptive users to achieve the desired growth rate; conversely, the second type of policies evaluate the reduction in growth rate of population for the assumed proportion of contraceptive users. In this paper, in addition to the first type of policies, we have derived a new contraceptive policy in order to get the desired growth rate and applied it to the sample registration system [3] data of Uttar Pradesh, India for illustration. Also, the consequences of these policies on population growth have been evaluated. The study population (Uttar Pradesh, India) justifies the assumption of a stable population since the birth and death rates in Uttar Pradesh have remained almost constant for several years.

## II. MATERIALS AND METHODS

### A. Contraceptive Policies

#### 1. Proportions of Contraceptive Users under Different Policies to Obtain the Desired Rate of Population Growth

It has been quoted that the cautious use of contraceptive policy can result in a sharp decline in the population growth [11].

The growth rate of population is determined by fertility and mortality behaviors alone and it can be explained by Lotka's integral equation, which is as follows:

$$\int_a^{\beta} \exp(-ra) p(a) m(a) da = 1$$

where  $p(a)$  is the proportion of the females in the population

that survives to age  $a$ ,  $m(a)$  is the probability that a female of age  $a$  will produce a female child in the next  $da$  period of her reproductive cycle, and  $\alpha$  and  $\beta$  are the lower and upper limits of the reproductive period.

If we want to achieve the desired rate of growth  $r^*$  from the current pace of growth  $r$ , then the following contraceptive policies can be worked out:

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

**Policy II:** A definite proportion  $f$  of the study population uses a protective device (contraceptive) at a particular age level  $x$ , and a certain proportion  $\sigma$  discontinue on reaching age  $y$  ( $x < y < \beta$ ).

**Policy III:** A continued stream of contraceptive users at two age levels  $x$  and  $y$  independently.

In a sequence of above strategies suggested by [12], we have proposed the following contraceptive policy –IV which is given as below:

**Policy IV:** A certain proportion  $f$  of the population uses a contraceptive device at a certain age level  $x$ , a fixed proportion  $\sigma$  discontinue on reaching age  $y$  ( $x < y < \beta$ ), and a definite proportion  $\lambda$ , again continue the contraceptives at age  $z$  ( $y < z < \beta$ ).

Illustrations for the proportions of contraceptive users as per these policies are given in Appendix and explained by (2), (5), (8), and (11), respectively.

## 2. Reduction in the Growth Rate of Population for a Given Proportion of Contraceptive Users

In converse to the above four policies which evaluate the required proportion of contraceptive users for a certain drop in growth rate, policy V and policy VI were suggested by [12]. These policies evaluate the decline in growth rate for certain proportions of contraceptive users at different ages.

The declines in the rate of growth  $r$  are evaluated under the following policies [12]:

**Policy V:** A certain proportion  $f$  of the population uses a contraceptive method continuously after reaching age  $x$  ( $x < \beta$ ) and a certain proportion  $\sigma$  of the remaining females start using

at age  $y$  ( $y > x$ ). The remaining population uses contraceptives at age  $z$  ( $z > y > x$ ).

**Policy VI:** In addition to policy-V, the age at marriage is increased to  $k$  for  $k > \alpha$ .

Under policies V and VI, expressions for the reduction in the rate of growth  $r$ , are obtained in Appendix and are presented by (14) and (17), respectively.

The different population control policies for Uttar-Pradesh described above are illustrated with the help of the demographic data [3], published by the Registrar General of India. The different values of net maternity function  $p(a)$   $m(a)$  corresponding to different ages are required to illustrate the different contraceptive policies mentioned above. The values of  $m(a)$  are computed with the help of the [3] data, and the computational method is given in Appendix. The values of  $p(a)$  are chosen from (South model; level-19) [13]. We chose the level due to the similarity in mortality conditions between the region of study and the South model; level-19 in the regional Model Life Table. We have used the same data to compute the value of the rate of growth  $r$  and the other population parameters. The complete computational procedure is given in Appendix. Tables I and II present the values of  $p(a)$   $m(a)$ , the net maternity function;  $\mu$ , the mean length of generation time;  $R_0$ , the net reproduction rate; along with other population parameters.

**Example:** The proportion of females proposed for contraceptive usage at age 20 years to bring the present rate of growth 0.036 to 0.020, as per (2) is:

$$\frac{1.50550 - 1}{1.03232} = 0.48967$$

**Example:** The proportion of females proposed for contraceptive usage at age 20 years to bring the present rate of growth 0.036 to 0.015, as per (2) is:

$$\frac{1.69506 - 1}{1.17861} = 0.58972$$

TABLE I

VALUES OF  $R_0$ ,  $M$ ,  $R$ , AND NET MATERNITY FUNCTION  $P(A)$   $M(A)$  ALONG WITH THE COMPUTATION OF  $\exp(-R^*A)$   $P(A)$   $M(A)$  FOR PREDICTING THE PROPORTION OF CONTRACEPTIVE USERS TO ATTAIN THE RATE OF GROWTH  $R^* = 0.020$  FROM  $R = 0.036$

Age ( $z$ ) <sup>2</sup>	$p(a)$	$p(a) m(a)$	$\exp[-.02^*(z+2.5)] p(a) m(a)$	$[\exp(-r^*a)p(a)m(a)da]$
15	0.88592	0.67148	0.47318	1.50550
20	0.88076	0.81029	0.51666	1.03232
25	0.87374	0.55575	0.32064	0.51565
30	0.86562	0.23103	0.12061	0.19501
35	0.85641	0.10658	0.05035	0.07441
40	0.84569	0.04522	0.01933	0.02406
45	0.83210	0.01224	0.00473	0.00473

$$R_0 = 2.43 \quad \mu = 24.37 \quad r = 0.036$$

<sup>2</sup>Here  $z$  is the lower limit of the age class, e.g in class (15-20 years), 15 is the lower limit and  $a$  is the mid value of age class, e.g in class (15-20 years),  $(15+2.5) = 17.5$  is the age of female used for computing the proportions. Since calculated  $m(a)$  in table 4 is based on the age interval as (15-19 years), (20-24 years) ... (45-49 years),  $a$  is considered to be the mid value of age interval.

TABLE II

VALUES OF  $R_0$ ,  $M$ ,  $R$ , AND NET MATERNITY FUNCTION  $P(A)M(A)$  ALONG WITH THE COMPUTATION OF  $\exp(-R^*A)P(A)M(A)$  FOR PREDICTING THE PROPORTION OF CONTRACEPTIVE USERS TO ATTAIN THE RATE OF GROWTH  $R^* = 0.015$  FROM  $R = 0.036$

Age (z) <sup>1</sup>	$p(a)$	$p(a) m(a)$	$\exp[-0.015^*(z+2.5)] p(a) m(a)$	$\int \exp(-r^*a)p(a)m(a)da$
15	0.88592	0.67148	0.51645	1.69506
20	0.88076	0.81029	0.57818	1.17861
25	0.87374	0.55575	0.36790	0.60042
30	0.86562	0.23103	0.14189	0.23252
35	0.85641	0.10658	0.06073	0.09064
40	0.84569	0.04522	0.02390	0.02991
45	0.83210	0.01224	0.00600	0.00600

$$R_0 = 2.43 \quad \mu = 24.37 \quad r = 0.036$$

### III. ILLUSTRATIONS AND CONCLUSIONS

#### A. Assessment of Policies I-IV

##### 1. Assessment of the Policies under the Target Growth Rate of 0.02 from the Current Growth Rate 0.036

Let us assume a target annual growth rate for Uttar-Pradesh of 0.02 from the current growth rate 0.036 per year. The values of  $\exp(-r^*a)p(a)m(a)$  for  $r^* = 0.02$  are presented in Table I. Evaluating (2) for policy-I and the data (Table II), we have found that if females start using contraceptives continuously after age 20 years, about 49% of contraceptive users of the same age will be required to decrease the population growth rate from 0.036 to 0.02. Similarly, at age 25 years, about 98% contraceptive users are necessary for the same reduction in the rate of growth in the region if females start using contraceptives continuously after reaching age 25.

If we take  $x = 20$ ,  $y = 25$  and  $\sigma = 0.25$ , then for policy-II, from (5), it can be shown that about 61% of the females at 20 years of age need to adopt contraceptive devices in order to have the rate of growth from 0.036 to 0.02, assuming that 25% of the users would discontinue at the age of 25 years. In the case,  $x = 20$ ,  $y = 30$ , and  $\sigma = 0.25$ , about 54% of females are needed to start contraceptive methods at the age of 20 years to get a rate of growth of 0.02 assuming that 25% of the users would discontinue at the age of 30 years.

Under policy-III, if  $x = 20$ ,  $y = 25$  and  $f_2 = 0.20$ , then from (8), it is found that about 43% of females are imperative to use a contraceptive device at the age of 20 years to have a rate of growth of 0.02 per year, assuming that 20% of the females would adopt contraceptives at the age of 25 years.

Considering the proposed policy-IV, if  $x=20$ ,  $y=25$ ,  $z=30$ ,  $\sigma=0.40$ ,  $\lambda=0.30$ , then from (12), we can comment that at the age of 20 years, 42% of contraceptive users are required to reduce the present growth rate of 0.036 to 0.02, assuming that 40% of contraceptive users discontinue the use of contraceptive sat the age of 25 years and 30% again continue the contraceptive use at age 30 years. Table III and Fig. 1 present a snap shot for the Policy I to Policy IV.

##### 2. Assessment of the Policies under the Target Growth Rate of 0.015 from the Current Growth Rate 0.036

Let us assume a desired annual growth rate for Uttar-Pradesh of 0.015 from the current annual growth rate of 0.036. The values of  $\exp(-r^*a)p(a)m(a)$  for  $r^* = 0.015$  are calculated in Table II. Evaluating (2) for policy-I and the data

(Table II), we observed that if females start using contraceptives continuously after reaching age 20, about 59% of contraceptive users of the same age will be required to bring down the growth rate of Uttar-Pradesh from 0.036 to 0.015.

If we take  $x = 20$ ,  $y = 25$  and  $\sigma = 0.25$ , then for policy-II, from (5), it can be shown that about 72% of the females at 20 years of age need to adopt contraceptive methods in order to have a growth rate from 0.036 to 0.015, assuming that 25% of the users would discontinue at the age of 25 years. In the case  $x = 20$ ,  $y = 30$  and  $\sigma = 0.25$ , about 64% of females are needed to acquire contraceptive methods at the age of 20 years to get a rate of growth of 0.015 assuming that 25% of the users would discontinue at the age of 30 years.

Under policy-III, if  $x = 20$ ,  $y = 25$  and  $f_2 = 0.20$ , then from (8) it is found that about 54% of females are needed to use a contraceptive device at the age of 25 years to achieve a growth rate of 0.015, assuming that 20% of females would adopt contraceptives at the age of 25 years.

Considering the proposed policy-IV, if  $x=20$ ,  $y=25$ ,  $z=30$ ,  $\sigma=0.40$ ,  $\lambda=0.30$ , then for (12), we can comment that at the age of 20 years, 51% of contraceptive users are imperative to reduce the present growth rate of 0.036 to 0.015, assuming that 40% of contraceptive users discontinue the use of contraceptives at the age of 25 and 30% continue the contraceptive use at age 30 years.

Keeping the above illustrations in mind, it is worthwhile to mention that the proposed policy-IV is more feasible and correlates well with the current need of population control in Uttar-Pradesh, India.

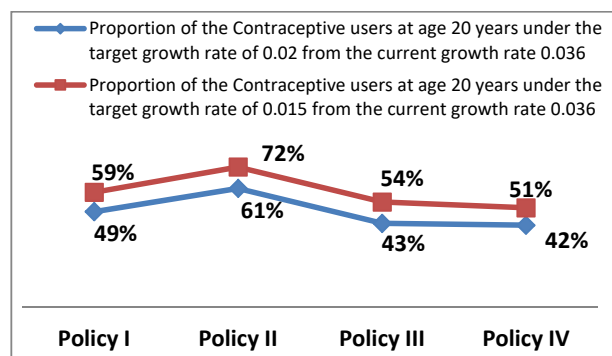


Fig. 1 Proportions of Required Contraceptive Users at Age 20 under Various Policies

TABLE III  
PARAMETERS AND REQUIRED PROPORTION OF CONTRACEPTIVE USERS AT AGE 20 YEARS

For Desired growth rate, $r=0.015$		For Desired growth rate, $r=0.020$	
Description of Policy	Required Proportion ( $f$ )	Description of Policy	Required Proportion ( $f$ )
Policy I ( $x=20$ )	0.59	Policy I ( $x=20$ )	0.49
Policy II ( $x=20, y=25, \sigma=0.25$ )	0.72	Policy II ( $x=20, y=25, \sigma=0.025$ )	0.61
Policy III ( $x=20, y=25, f_2=0.20$ )	0.54	Policy III ( $x=20, y=25, f_2=0.20$ )	0.43
Policy IV ( $x=20, y=25, z=30, \sigma=0.40, \lambda=0.30$ )	0.51	Policy IV ( $x=20, y=25, z=30, \sigma=0.40, \lambda=0.30$ )	0.42

### B. Assessment of Policies V and VI

To illustrate the policy V and policy VI, the values of  $f, \sigma, x, y$ , and  $z$  are required. To make the selections of ages rational, the values of  $x, y$  and  $z$  are taken, approximately as the median ages of women at first, second, and third parity, respectively. Since the data on the median age of females at certain parity's is not available in [3], we have computed it from the data [14] and it is obtained at first, second, and third parity as 23 years, 28 years and 32 years, respectively. Thus, the values of  $x, y$  and  $z$  have been taken as 23 years, 28 years and 32 years, respectively. Since the value of  $p(a)$  is not available in the model life table corresponding the ages 23 years, 28 years, and 32 years, the value of  $\exp(-r^* a) p(a) m(a)$  are interpolated. A proper choice of an interpolation formula is largely responsible for the accuracy of the estimates [16]. Therefore, Newton's forward interpolation formula has been used to estimate the above expression for female aged 23 years and Gauss' forward interpolation formula has been used to estimate the above expression for females aged 28 years and 32 years.

Taking  $x = 23, y = 28, z = 32, f = 0.75$ , and  $\sigma = 0.50$  in (14), then under policy-V, we have the value of  $\Delta r$ , the reduction in  $r$  as:

$$\Delta r = 0.004, \text{ with } R_0 = 2.18$$

From (17), under policy-VI with  $f = 0.75$ , and  $\sigma = 0.50, x = 23, y = 28, z = 32$ , and  $k = 20$ , we get:

$$\Delta r = 0.019, \text{ with } R_0 = 1.53$$

It is worthwhile to mention that reduction in the rate of growth through policy-VI expressed by (15) is significantly more than that of policy-V represented by (17), and this may be due to the fact that the fertility between the ages 15 years to 20 years is still very high in Uttar-Pradesh, India. In India, due to the cultural barriers, birth before marriage is not accepted socially. Therefore, a data constraint exists on the fertility before marriage and it is a convention in most of the large scale surveys to consider that no births occur before marriage in India. Therefore, in (16),  $m(a)$  i.e. the probability of having a female child is considered to be zero if  $a < k$  (age at first marriage) since there is zero probability of birth before marriage as per the data gap. Hence, we can conclude that the high fertility in age group (15-20 years) is only due to the low marriage age in the region. Therefore, increasing the marriage age along with the contraceptives use at different ages is the key solution for the population control in the region.

### APPENDIX

Reference [10] has derived that when a proportion  $f$  of the population uses any contraceptive device on attaining age  $x$ , ( $x < \beta$  and  $0 \leq f \leq 1$ ) the declined rate of growth  $r^*$  satisfies;

$$\int_x^\beta \exp(-r^* a) p(a) m'(a) da = 1 \quad (1)$$

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

Solving (1) for  $f$ ,

$$f = \frac{\int_x^\beta \exp(-r^* a) p(a) m(a) da - 1}{\int_x^\beta \exp(-r^* a) p(a) m(a) da} \quad (2)$$

Expression (2) can be used to find the proportion of females at age  $x$  that would be expected to use the contraceptive device (under policy-I) for the desired rate of growth  $r^*$ .

Under policy-II, in the case of contraceptive device use like oral pills, condoms, I.U.C.D (Intrauterine Contraceptive Device) etc., if a specific proportion of  $f$  ( $0 \leq f \leq 1$ ) of the population uses contraceptives on reaching age  $x$  and a specific proportion  $\sigma$  ( $\sigma < f$ ) discontinues on reaching age  $y$  ( $x < y < \beta$ ), then the declined rate of growth,  $r^*$  fulfils;

$$\int_x^\beta \exp(-r^* a) p(a) m''(a) da = 1 \quad (3)$$

$$\text{With, } m''(a) = \begin{cases} m(a) & \text{if } a < x \\ (1-f) m(a) & \text{if } x \leq a < y \\ (1-f+\sigma) m(a) & \text{if } a \geq y \end{cases} \quad (4)$$

Solving (3) for  $f$ ,

$$f = \frac{\int_x^\beta \exp(-r^* a) p(a) m(a) da + \sigma \int_y^\beta \exp(-r^* a) p(a) m(a) da - 1}{\int_x^\beta \exp(-r^* a) p(a) m(a) da} \quad (5)$$

Thus, for an assumed value of  $\sigma$  (discontinuation rate), the value of  $f$  can be computed for the desired reduction in the growth rate.

Under policy-III, if there exist continued stream of

contraceptive users at two ages,  $x$ , and  $y$ , then the reduced growth rate  $r^*$  satisfies;

$$\int_{\alpha}^{\beta} \exp(-r^* a) p(a) m^{III}(a) da = 1 \quad (6)$$

$$\text{With, } m^{III}(a) = \begin{cases} m(a) & \text{if } a < x \\ (1-f_1) m(a) & \text{if } x \leq a < y \\ (1-f_1)(1-f_2) m(a) & \text{if } a \geq y \end{cases} \quad (7)$$

where,  $f_1$  and  $f_2$  give the proportions of contraceptive users at ages  $x$  and  $y$  individually. Solving (6) for (7), we found;

$$f_1 = \frac{\int_{\alpha}^{\beta} \exp(-r^* a) p(a) m(a) da - f_2 \int_{\alpha}^{\beta} \exp(-r^* a) p(a) m(a) da - 1}{\int_{\alpha}^{\beta} \exp(-r^* a) p(a) m(a) da - f_2 \int_{\alpha}^{\beta} \exp(-r^* a) p(a) m(a) da} \quad (8)$$

For a given  $r^*$  and  $f_2$ ,  $f_1$  can be evaluated with (8). The similar expression for  $f_2$  in terms of  $f_1$  and  $r^*$  can be worked

$$f_2 = \frac{\int_{\alpha}^{\beta} \exp(-r^* a) p(a) m(a) da + \sigma \int_{\alpha}^{\beta} \exp(-r^* a) p(a) m(a) da - \lambda \int_{\alpha}^{\beta} \exp(-r^* a) p(a) m(a) da - 1}{\int_{\alpha}^{\beta} \exp(-r^* a) p(a) m(a) da} \quad (11)$$

Under policy-V, when a proportion  $f$  of the population uses any contraceptive device continuously on attaining age  $x$ , and a fixed proportion  $\sigma$  of the left population uses at age  $y$  ( $y > x$ ), and the remaining population uses the contraceptives at the age  $z$  ( $z > y > x$ ), the new rate of growth,  $r'$  satisfies:

$$\int_{\alpha}^{\beta} \exp(-r' a) p(a) m^V(a) da = 1 \quad (12)$$

out.

Considering the proposed policy IV, if a certain proportion of  $f$  ( $0 \leq f \leq 1$ ) of the population uses contraceptive devices on reaching age  $x$ , further a certain proportion  $\sigma$  ( $\sigma \leq f$ ) discontinues on reaching age  $y$  ( $x < y < \beta$ ), and a certain proportion (who achieved their desired parity)  $\lambda$  ( $\lambda < \sigma$ ) again start using contraceptives at age  $z$ , then the new rate of growth,  $r^*$  satisfies;

$$\int_{\alpha}^{\beta} \exp(-r^* a) p(a) m^{IV}(a) da = 1 \quad (9)$$

$$\text{With, } m^{IV}(a) = \begin{cases} m(a) & \text{if } a < x \\ (1-f) m(a) & \text{if } x \leq a < y \\ (1-f+\sigma) m(a) & \text{if } y \leq a < z \\ (1-f+\sigma-\lambda) m(a) & \text{if } a \geq z \end{cases} \quad (10)$$

Solving (10) for  $f$ ,

$$\text{With, } m^V(a) = \begin{cases} m(a) & \text{if } a < x \\ (1-f) m(a) & \text{if } x \leq a < y \\ (1-\sigma)(1-f) m(a) & \text{if } y \leq a < z \\ 0 & \text{if } a \geq z \end{cases} \quad (13)$$

where,  $r' = r + \Delta_r$ .  $\Delta_r$  is the reduction in the growth rate  $r$ . If  $\Delta_r$  is small enough that,

$$\exp(-\Delta_r)_a \approx 1 - (\Delta_r)_a$$

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

$$\Delta_r \approx \frac{f \int_{\alpha}^{\beta} \exp(-ra) p(a) m(a) da + \sigma(1-f) \int_{\alpha}^{\beta} \exp(-ra) p(a) m(a) da - \int_{\alpha}^{\beta} \exp(-ra) p(a) m(a) da + 1}{\int_{\alpha}^{\beta} a \exp(-ra) p(a) m(a) da} \quad (14)$$

It has been advised that the increase in the age at marriage may be considered as a technique of controlling the growth of population. If the age at marriage is increased to  $k$  years for  $k > a$ , as a supplement to the policy V, then under policy VI, the new rate of growth,  $r'$  satisfies:

$$\int_{\alpha}^{\beta} \exp(-r' a) p(a) m^{VI}(a) da = 1 \quad (15)$$

$$\text{With, } m^{VI}(a) = \begin{cases} 0 & \text{if } a < k \\ m(a) & \text{if } k \leq a < x \\ (1-f) m(a) & \text{if } x \leq a < y \\ (1-\sigma)(1-f) m(a) & \text{if } y \leq a < z \\ 0 & \text{if } a \geq z \end{cases} \quad (16)$$

The value of  $\Delta_r$  can be obtained under policy VI with the fertility schedule (17), as follows:

$$\Delta_r \approx \frac{f \int_x^z \exp(-ra) p(a) m(a) da + \sigma(1-f) \int_y^z \exp(-ra) p(a) m(a) da - \int_k^z \exp(-ra) p(a) m(a) da + 1}{\int_k^z a \exp(-ra) p(a) m(a) da} \quad (17)$$

### Computational Procedure

The current growth rate of Uttar Pradesh is computed by using the standard formula of stable population [15] as:

$$r = \log R_0 / T \quad (18)$$

where  $T$  is the mean length of the generation in the stable population. Mean length of the generation or average generation length is the average age of mother of a number of children, either in one generation or across several generations. For example: If a woman gives birth to three children when aged 28 years, 32 years and 35 years, then the average generation length is 31.6 years  $((28 + 32 + 35)/3 = 31.6)$ .

### Computation of $m(a)$

The number of births occurring during a given year or reference period per 1,000 women of reproductive age classified in single-or five-year age groups is termed as age-specific fertility rates (ASFR). Since the computation of ASFR includes all the women irrespective of their marital status [12], multiply ASFR by the proportion of eligible women of the particular age-group. Due to the unavailability of data on the proportion of eligible women in [3], Age specific marital fertility rates (ASMFR) have been used for each age group. Further, multiplying by sex-ratio and five (due to 5-yearly age-group), the values of  $m(a)$  can be obtained as follows:

$$m(a) = ASMFR \times Q \times 5 \quad (19)$$

where  $Q$  is the sex-ratio at birth. The value of  $Q$  in Uttar Pradesh as per [3] data, is 0.467 female births per birth and the values of  $Q$  along with ASMFR are presented in Table IV.

TABLE IV  
THE VALUES OF AGE-SPECIFIC MARITAL FERTILITY RATES (ASMFR),  
VALUES OF  $M(a)$  AND  $P(a)$  VALUES OBTAINED FROM MODEL LIFE TABLE FOR  
EACH AGE GROUP

Age group	ASMFR	$m(a)$	$p(a)$
15-19	0.32460	0.75794	0.88592
20-24	0.39400	0.91999	0.88076
25-29	0.27240	0.63605	0.87374
30-34	0.11430	0.26689	0.86562
35-39	0.05330	0.12446	0.85641
40-44	0.02290	0.05347	0.84569
45-49	0.00630	0.01471	0.83210

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