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Population and Ageing in India: Some Projections Based on Stable Population Theory

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Abstract
Introduction: Population ageing occurs when an initially growing population starts decling and progress towards replacement level.The studies on stable population initiated by Coale, Demeny, Keyfitz and others in the middle of the 20th century have received momentum in recent days among population scientists and researchers working on these areas. Objective:The aim of this paper is to work out the size of India's population in future to come and trend of aging/elderly population (aged 60 and above) through some models based on the stable population theory. Results & Conclusion: Based on a set of hypothetical and realistic data, it has been found that at the time of stabilisation of India's population (when r=0), more than one fifth of India would be above sixty years. It is also seen that if the present trend of decling growth rate exists, its population would be about 169 billion by 2051.It is hoped that the proposed models would be helpful for policy makers and researchers to have some idea about the future trend of India's population and elderly population.

Keywords: *Stable Population, Stationay Population, Total Fertility Rate, Population Growth Rate, Ageing.*

Introduction

No doubt present India is young-more people in working age group (15-59), but the way population of India is growing older resulting into a higher absolute number of aged people (60^+), longer life expectancies and relatively low number of persons in youngest age group (0-14) due to declining fertility over the last few decades warrants to a number of unexplored demographic parameters

Ageing in Global Scenario

As on today (2020) at the end of second decade of the 21st century (this year or period will be remembered by GOVID-19), about 9 per cent of the world population is aged 65 and above with a high regional variations. Japan has the highest percentage (28) followed by Italy (23), U.K. (18), U.S.A. (16) and Russian Federation (15) of the elderly people (World Population Prospects 2019). Among South Asian countries China tops with 11 per cent followed by Sri Lanka (10%) of the elderly people aged 65 and above. The percentage elderly (65^+) in India is about 6. If the Global scenario of the elderly people is put up in another way, it has been reported that developed nations have more than or equal to 15 per cent of the elderly people, whereas developing and under developed countries respectively have (6-14) and less than or equal to 6 per cent of the elderly people. More specifically, high income group countries have about 18 per cent elderly (65^+) followed by upper middle (10%), middle (8%) and low (3%) income group countries. However, it should be noted that although the percentage of elderly people in South Asian countries like India looks lower at present but its absolute number is much higher than the many developed countries combined together (Indian Census, 2011).

In Indian Context

As mentioned above, India's population constitutes 8.6 per cent elderly people (60^+) as per Census-2011 which is projected about 10 per cent by 2021 (Technical Group Report on Population Projection (2011-2036), Nov. 2019). In India too, there has been regional variation in the percentage of elderly people from North to South and from East to West. Taking two to three major states of each zone, it has been reported that average percentage of elderly people in Southern States (based on Kerala and Tamil Nadu) is highest (about 15%) followed by West (11%) based on Gujrat and Maharastra. The percentage elderly people in the East Zone (based on Assam and West Bengal) has been reported about 10 and a lowest about 8% of elderly in North (based on U.P., M.P. and Bihar). The state-wise such variation in the percentage of the elderly people is in conformity with the fertility and hence annual growth of the population. A number of projections of total population and elderly people have been made by several researchers both at global and national levels (Islam and Nath, 2010, Keyfitz, 1968, Pandey and Yadava, 2017 and others). The reliability of a projected value depends on the validity of the assumptions made about the demographic parameters and their trends in future to come at the base stage of the projection. In stable population theory there are several formulae (models) for population projections and when applied give more or less accurate results provided used population is stable in nature.

Stable Population

A population (closed to migration) with a regime of unchanging fertility and mortality schedules for a long time is called the stable population. Such population has a fixed age structure and the size of the population changes with a constant rate of increase r, which depends on such fertility and mortality schedules. A fundamental equation of the stable population (Coale, 1972; Keyfitz, 1968) is :

$$\int_{\alpha}^{\beta} e^{-ra} p(a) n(a)\, da = 1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,

p(a): the fraction of female population that survives to age x

m(a): probability, that a female who is of age x will bear a female child in next da period of her life; α and β: lower and upper limits of the reproductive period.

When r=0, then age structure of population becomes constant with NRR=1 and then it is called stationary population.

Based on this fundamental equation (1), a number of population growth models have been proposed (Fraunthal, 1975; Goldstein, 2002; Sing et al, 1981; Yadava et al, 1996, 2001 and many others). Short term $t \leq \alpha$ and long term $t > \alpha$ population projection models have also been developed by taking abrupt and gradual decline in fertility schedule m(a) (Yadava, 1985; Yadava et al, 1996).

The objective of this paper is to propose some models under stable population with reasonable assumptions for future population of India and proportion of elderly people for different values of r.

The suitability of models proposed has been discussed in Indian context taking some real data (Indian Census 2001, 2011) and hypothetical set of data (Regional Model Life Table of Coale and Demeny, 1966). Models are discussed with female sex only. Males and hence total population can be worked out with usual formulae.

Methodologies and Models

Stable Population

Based on the fundamental equation (1), a formula for the future population under the stability conditions comes out (Coale, 1972 and Keyfitz, 1968) as

$$P_t = P_0\, e^{rt} \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

where P_t and P_0 are population at time t and initial time o; r is the stable growth rate.

This model (2) overestimate the size of population for the large value of t if population is not stable or stability conditions do not continue with the same r for the longer period. As mentioned above, looking on the recent declining trend of growth rate of India, it is necessarily not a stable population. However, its future population is projected with a reasonable modification to model (2) as

$$P_t = P_0\, e^{r^* t} \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

where,

$$r^* = \left(1 - \frac{1}{TFR}\right) r \qquad \ldots\ldots\ldots\ldots(4)$$

TFR: Total Fertility Rate.

Aged Population

In a stable population proportion of aged population (60+) is given as

$$P_{60^+} = \frac{\int_{60}^{\omega} l_x\, d_x}{\int_{0}^{\omega} l_x\, d_x} \qquad \ldots\ldots\ldots(5)$$

where,

l_x is the number of survivors at exact age x and w is the highest age of life.

However, above equation (5) does not show the increasing or decreasing trend in aged population with r.

As such, Keyfitz (1977) modified and expanded expression (5) as:

$$P_{60^+} = \frac{\int_{0}^{\omega} l_x\, d_x}{\int_{0}^{\omega} l_x\, d_x} \left[e^{-(m_3 - m_2)r - (\sigma_2^2 - \sigma_3^2) r^2} \right] \qquad \ldots\ldots(6)$$

i.e

$$P_{60^+} = \bar{A}_{60}\, e^{*} \qquad \ldots\ldots\ldots(7)$$

where,

$$e^{*} = e^{-(m_3 - m_2)r - \left(\frac{\sigma_2^2 - \sigma_3^2}{2}\right) r^2} \qquad \ldots\ldots\ldots(8)$$

m_2 and σ_2^2 are respectively the mean and variance of stationary population; and m_3 and σ_3^2 are mean and variance of those aged 60 and above respectively.

Expression (6) can be used to compute the proportion of elderly population and may be compared for many other populations closed to migration. Pandey and Yadava (2017) modified the expression (6) saying that this model does not tells anything when population growth rate (r) changes over time from one condition to another. In that situation, the demographic parameters including mean(m) and variance(σ2) also change. Taking this into account, they modified equation (6) as

$$P_{60^+} = \bar{A}_{60}\, e^{**} \qquad \text{……..(9)}$$

where,

$$e^{**} = e^{-(m_3-m_2)A^*r-\left(\frac{\sigma_2^2-\sigma_3^2}{2}\right)r^2} \qquad \text{……..…..(10)}$$

with,

$$A^* = \left[1+\frac{\bar{x}_w}{(m_2-m_1)}100r\right] \qquad \text{……(11)}$$

and

$$\bar{x}_w = \frac{\sum d_i r_i}{\sum r_i} \qquad \text{……..(12)}$$

di : difference ($m_3 - m_2$) from r_i to r_{i+1} (i=0,1,.....)

Modification proposed by Pandey and Yadava seems to be orbitrary where no reason of choosing A^* has been mentioned. Keeping this into account, the value of A^* is taken as follow

$$A^* = \left(1+\frac{m_1}{\sigma_1^2}\right) \qquad \text{……(13)}$$

where m_1 and σ_1^2 are mean and variance of the stationary population of the age group (0-14). This youngest age group is included knowing that this group shows immediate impact of fertility transition of a nation which later influenced the magnitude of the elderly population. Thus the proportion of elderly population is projected by the model given below;

$$P_{60^+} = \frac{\int_0^\omega l_x d_x}{\int_0^\omega l_x d_x}\left[e^{-(m_3-m_2)A^*r-\left(\frac{\sigma_2^2-\sigma_3^2}{2}\right)r^2}\right] \qquad \text{……...(14)}$$

where A^* is defined by equation (13)

Further, it should be noted that stabilization means not the state of stationary for a longer time. Population further would increase or decrease with some growth rate in new regime of fertility schedule. If the population starts increasing with a small growth rate r^* in the new regime of fertility schedule, then the proportion of elderly population may follow the following model

$$P_{60^+} = \frac{\int_{60}^\omega l_x d_x}{\int_0^\omega l_x d_x} e^{r*t} \qquad \text{……(15)}$$

Results and Discussion

As mentioned in the introductory section population and the elderly population (60^+) of India are projected taking Census year 2011 as the base period. From the Regional Model Life Table (Coale and Demeny, 1966), South Level 20 (female) was chosen a reasonable state of stationary population of India. The values of various demographic parameters are noted and/or computed. With P_o=121 billion, TFR=2.1 and r=0.016 (India Census, 2011), the projected population by models (2) and (3) are given in Table 1.

Table 1: Projected population (in billion) of India with base Census Year 2011.

Time (t)	$P_t = P_0 e^{rt}$	$P_t = P_0 e^{r*t}$
2021	209	132
2031	246	143
2041	289	155
2051	**339**	**169**
2061	398	184
2071	468	200

With the proposed model, India's population would be 169 billion which is consistent with the World Population Data Sheet, 2019 where it reports that India's population will surpass China by 2050 with 167 billion people.

Now for the elderly population by expression (14) shows that when the India,s population will stabilize i.e. at the stage when r=0, then from (14)

$$P_{60^+} = P^{stb}(60, w) \qquad \text{... ... ... (16)}$$

i.e.

$$P_{60^+} = 22.23$$

(From the Regional Model Life Table (South Level 20, 21) (Coale and Demeney, 1966). That is, at the stage of stabilization the proportion of the elderly people in the country would be more than one fifth of the total population. The reliability of this projection of elderly population can be looked from the following Table 2 making a backward projection of this very population.

Table 2: Projected percentage population of elderly in India (Aged 60 and above)

r	$+P_{60^+}$(Model, 14)	$++P_{60^+}$(Model 14)
0.000	22.23	22.23
0.001	21.68	20.89
o.005	18.69	16.41
0.010	15.20	12.13
0.015	11.78	8.96
0.016* **(Census 2011)**	9.71	8.36 (8.6*)
0.019** **(Census 2001)**	8.17	6.62 (6.9**)

* and ** *show the observed growth rate and the percentage of elderly population of India as per Census 2011 and 2001 respectively.*

$+P_{60^+}$ *: m_1 , m_2, m_3, σ_1^2 σ_2^2 and σ_3^2 are computed based on Model Life Table (South Level 20,21) (Coale and Demeney, 1966).*

$++P_{60^+}$ *: m_1 , m_2, m_3, σ_1^2 σ_2^2 and σ_3^2 are computed based on the age structure of Indian Census 2011 data*

From the above Table 2 it seems that the proposed model (14) gives a reasonable approximation of the magnitude of the elderly population according to its growth rate. However, this model does not say anything about the time when India's population will stabilise, that is, when growth rate would approach to zero. As mentioned above, though India's population is not stable as on today (year 2020), but the way its growth rate is declining since last 2-3 decades, it is expected that country's population may stabilize somewhere around 2051. If population increases with a minimum growth rate of 0.001 or 0.005 after stabilization, then by model (15), the percentage of elderly population would be (see Table 3)

Table 3: Projected percentage of elderly population of India after stabilization in 2051

Time (t)		Model (15)	Model (15)
	r^*=0.000	r^*=0.001	r^*=0.005
2051	22.23		
2061		22.45	23.34
2071		22.68	24.51
2081		22.90	25.73
2091		23.13	27.02
2101		23.36	28.37

Table 3 shows that by the end of 21st century, about 28 % population of India would be aged 60 and above if after 2051 population grow by 5 per thousand population. It should be noted that at present Japan has had about 28 % population aged 65^+ which has now a decreasing growth rate.

Conclusions

With base 2011census year, it was found that India,s population would be about 169 billion by 2051, if the assumed demographic parameters continue as shown in the paper. The proposed model for the projection of the elderly population reasonably satisfied the observed figure of the aged people. Based on the recent declining trend of India, growth rate, it was expected the population of the country would stabilize around 2051 abd by that time more than one fifth (about 22%) population would be aged 60 and above. It was also found that if population further increase after stabilization with a small growth rate of 0.005, then the about 28 % population would be aged 60 and above by the end of 21st century.

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