

MAXIMUM LIFESPAN IN INDIA

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1. Introduction

Life expectancy at birth is often used as a measure of mortality. It is an important indicator of population health. In the historical as well as current population, high rates of infant and early childhood mortality result in lower values of life expectancy at birth than at the other ages. In such populations, those surviving the hazards of early childhood have a higher life expectancy than newborns and the highest life expectancy occurs not at birth but at a later age. With increasing life expectancy at birth, the maximum longevity that a population achieves gains extreme importance. Much demographic literature suggests that the human life span does not approach a fixed limit imposed by biology or other factors. Both average life expectancy and maximum human life span have increased steadily for more than a century (Wilmoth & Robine, 2003). Wilmoth and Lundstrom (1996) showed that the upper tail of the age distribution of deaths has moved steadily higher over a period of at least 130 years in Sweden. This clearly suggests that a large number of persons are surviving to higher age groups in developed countries. Oeppen and Vaupel (2002) analyzed data from several countries in the world and found that the record life expectancy at birth has increased in the world. Wilmoth et al., (2000) attributed the increase in lifespan in the second half of the twentieth century to a combination of larger cohorts surviving to old ages, and to improvements in survival after these ages.

Studies of extreme longevity provide another way to examine the improvement in mortality levels of a country. The increase in extreme longevity suggests greater chances of people surviving till maximum old age. There are different approaches to study the extreme longevity in a population. Several demographers have used maximum age at death to study extreme longevity (Wilmoth & Lundstrom, 1996; Han, 2005). Some studies suggest that measures such as modal age at death or standard deviation above modal age at death also provide some useful insights in understanding longevity. Maximum remaining life expectancy or maximum expected longevity is also used to provide similar useful insights on extreme longevity in any population. These measures are unique in the sense that they combine information about mortality in early life with the expected length of life of those who have surpassed the risk of death in infancy.

To understand the extremities of the level of longevity, it is advised to go beyond these general measures. This paper is an attempt to study the extreme longevity in India utilizing maximum remaining life expectancy or maximum expected longevity as an outcome measure. These indicators were estimated for India and its major states to provide useful information on mortality improvement in India. The analysis was carried out in three main steps. First, the trends and patterns of extreme longevity for different subgroups of the population in India were examined. Second, the increase in extreme longevity was analyzed with the improvement in life expectancy at birth. Third, with the help of the maximum remaining life expectancy or maximum expected longevity estimates for the major states, the record maximum remaining life expectancy and record maximum expected longevity was estimated for each time period in India. This analysis would answer the question of whether the similar state has acquired this record, or has changed from 1970-75 to 2006-10 from one state to other. The next section provides the methodological details of the measures used to examine extreme longevity.

2. Data and Methods

Sample Registration System (SRS) is the main and continuous source of data on mortality and life tables in India. The data on death rates along with the abridged life tables from 1970 to 2010 provided by SRS has been used in this paper.

With the recent observations of the error in the life tables reported by Saikia et al., (2010) abridged life tables for the period of 1996-2000 to 2006-10 were reconstructed. The age-specific death rates in the

usual broad age groups – from 0-1, 1-4, 5-9...., 80-84, 85+ are available for each year. In order to get age-specific death rate for the time period 1996-2000; 2001-05; 2006-10 for each age group, we averaged the age-specific death rate of the five years. This was used as the input for constructing the abridged life tables using Mortpak software (UN, 2003). The abridged ${}_nq_x$ values are split into single year ${}_1q_x$ values using the parametric technique of Heligman and Pollard (1980) with the help of Mortpak, which provides smooth results for single year ${}_1q_x$ values. Heligman-Pollard equation. Because of the poor fit of the Heligman-Pollard equation for the six selected time period in three states for urban females, simple six point lagrange interpolation techniques to expand abridged ${}_nq_x$ values as suggested in Elandt-Johnson and Johnson (1980) was used.

In order to check the goodness of the model-based estimates, we plotted all the ${}_nq_x$ values for the age groups 0-1, 1-5, 5-10 and so on up to 85+ years for the abridged life tables from 1970-1975 to 2006-2010 for the major states and India. These values were plotted against the fitted ${}_nq_x$ values obtained from the Heligman-Pollard equation. The results show that there is a close correspondence between the observed and fitted values of ${}_nq_x$. The difference in observed and fitted values is not noticeable in the younger age groups for India and both the states and the values lies in a straight line. However, a minimal difference has been observed in the older age groups. The smoothed ${}_nq_x$ values obtained from Heligman-Pollard equation are segregated into ${}_1q_x$ values. The complete life table has been prepared using the single year ${}_1q_x$ values. The complete life tables prepared for the time period of 1970-75 to 2006-10 were used subsequently as the input for estimating the indicators.

The measures discussed below are proposed by Romo and Engelman (2009) to study the maximum life expectancies and their trends for the countries over a long period of time. I am using these measures to estimate the maximum life expectancies and maximum expected longevity over time for India and its major states by sex and place of residence from 1970-75 to 2006-10.

Let $e_x^i(t)$ denote the remaining life expectancy at age x , for state i , and time t ; $e_x^i(t)$ represents the average number of years that those surviving to age x are expected to live, if they were to follow the death rates observed at time t . The sum of the remaining life expectancy $e_x^i(t)$ and the age x at which it occurs is the total number of years that survivors to age x are expected to live. We refer to this measure as the total expected longevity and calculate it as:

$$e_{T_x}^i(t) = e_x^i(t) + x \quad (1)$$

From the age-specific life expectancy measures, the maximum remaining life expectancy for state i at time t can be calculated as:

$$e_m^i(t) = \max_x [e_x^i(t)] \quad (2)$$

Maximum remaining life expectancy is a conditional measure of central tendency that reflects the effect of premature deaths while also providing a better estimate of the survivors' expected longevity than e_0 . It is also possible to express the maximum total expected longevity as:

$$e_{T_m}^i(t) = e_m^i(t) + x_m^i(t) \quad (3)$$

where $x_m^i(t)$ represents the life table age where the maximum remaining life expectancy $e_m^i(t)$, occurs.

Total maximum expected longevity uniquely combines information about mortality in early life (by indicating the age at which life expectancy reaches its highest level, if the maximum expectation is not achieved at birth) with the expected length of life for those who do survive the hazard of mortality in infancy.

In this chapter, the trends in record remaining life expectancy and record total expected longevity over time was examined. Oeppen and Vaupel (2002) introduced the idea of calculating the maximum life expectancy at birth for every year, a measure known as record life expectancy at birth. Let $e_0^i(t)$ be the life expectancy at birth for state i at time t . The record life expectancy is calculated as:

$$e_{r_0}^i(t) = \max_i[e_0^i(t)] \quad (4)$$

In addition to finding the maximum life expectancy at birth across all states, it is also possible to obtain the record remaining life expectancy at time t , calculated from equation (2) as:

$$e_m^i(t) = \max_i[e_x^i(t)] \quad (5)$$

It should be noted that while the maximum value in equation (2) is calculated over age, in record measures (4) and (5) the maximum is calculated across the states. The new record $e_m^i(t)$ is an expectancy value that may occur at any age and which, in the states with available data, ranges across the childhood years. Thus, it is useful to consider the total number of years lived on average by the group with a particular life expectancy at age x . Similar to equations (1) and (3), the record total expected longevity is calculated as the sum of the record remaining life expectancy and the number of years already lived up to the age where this maximum occurs.

All these indicators for India can also be estimated using similar formulas, except that the subscript i can be removed from all the formulas. Hence, remaining life expectancy is written as $e_x(t)$ and total expected longevity is written as $e_{T_x}(t)$. The maximum remaining life expectancy for India is calculated as:

$$e_m(t) = \max_x[e_x(t)] \quad (6)$$

And maximum expected longevity can be calculated as:

$$e_{T_m}(t) = e_m(t) + x_m(t) \quad (7)$$

For India, the two indicators described above are calculated by sex and place of residence from 1970-75 to 2006-10.

3. Results

By investigating maximum life expectancy at birth or other ages, maximum expected longevity and its associated record measures allow us to understand improvements in survival not only as an indicator of change over time, but also, notably, as functions of age.

Change in Total Expected Longevity and Remaining Life Expectancy by Age

For any country, the maximum life expectancy exceeds life expectancy at birth until both reaches high levels. Figure 1 and 2 presents the trajectories of remaining life expectancy (e_x), and total expected longevity (e_{T_x}), for males and females in India during 1970-75 and 2006-10. In 1970-75, life expectancy at birth for males was only higher than the remaining life expectancy at age 14 years. Over time, this differential decreased, and the age trend of the remaining life expectancy became a monotonic decreasing function. By 2006-10, only remaining life expectancy at age 5 was higher than at birth. Similar figures for females can be observed at age 17 and age 6. The patterns over time for females and males were quite similar. With the remaining life expectancy trajectory shifted upwards, the expected longevity trajectory also shifted up. The largest gain in expected longevity was observed in the early ages. At older ages, the rise in expected longevity is steeper, suggesting that survivors are no longer limited by the constraints of the mean life duration.

Figure 1: India Males: Remaining Life Expectancy (e_x), and Total Expected Longevity (e_{T_x}) in 1970-75 and 2006-10

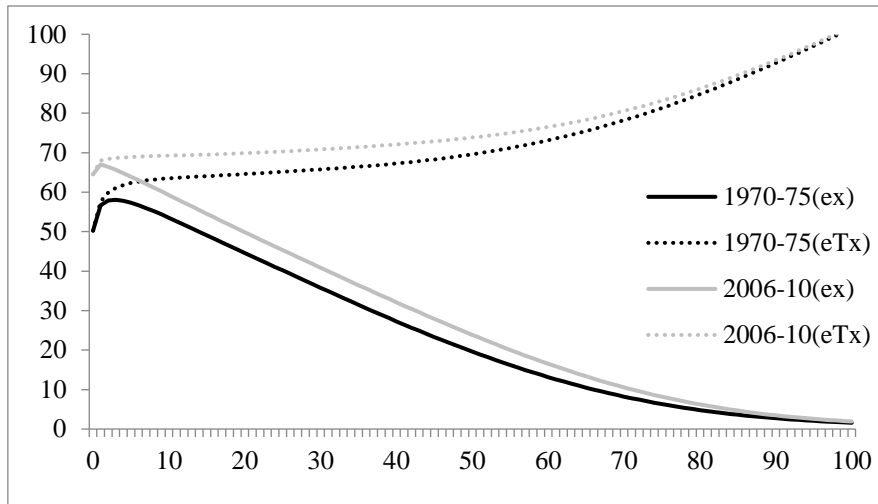
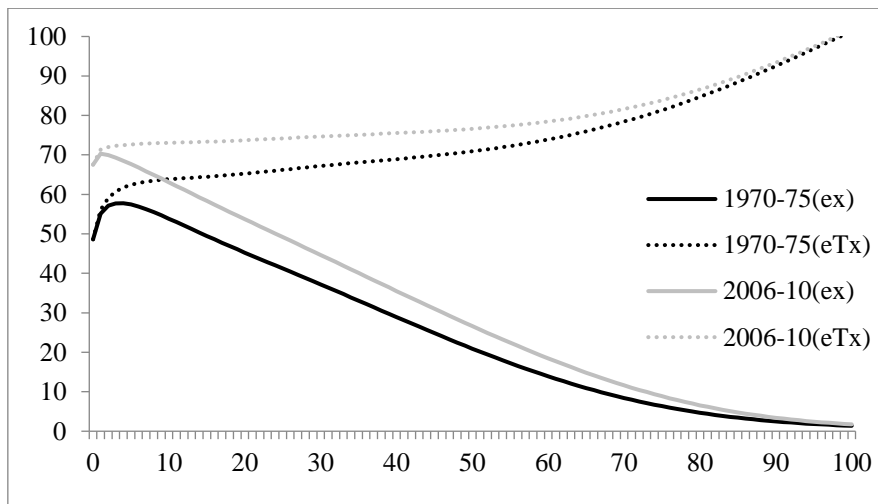


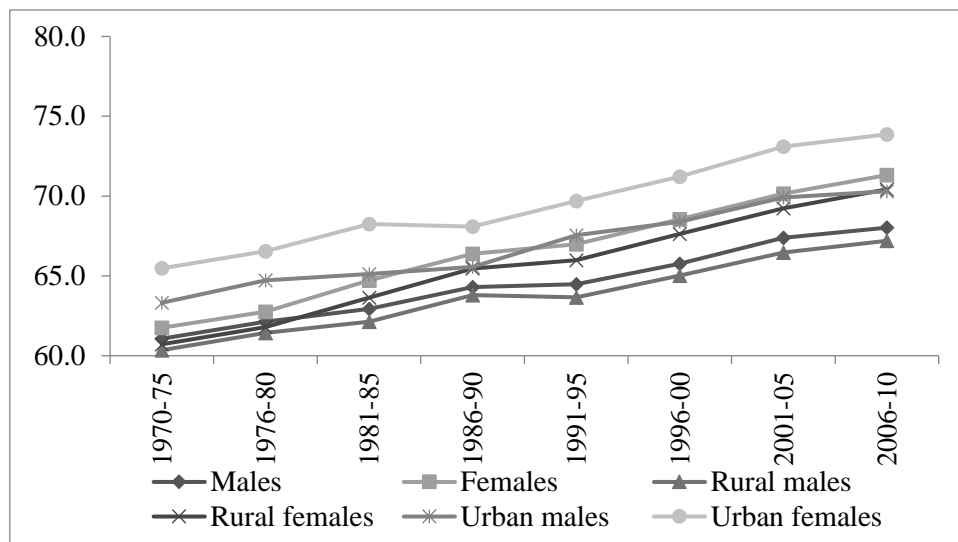
Figure 2: India Females: Remaining Life Expectancy (e_x), and Total Expected Longevity (e_{Tx}) in 1970-75 and 2006-10



Trend in Maximum Total Expected Longevity in India and its Relation with Life Expectancy at Birth

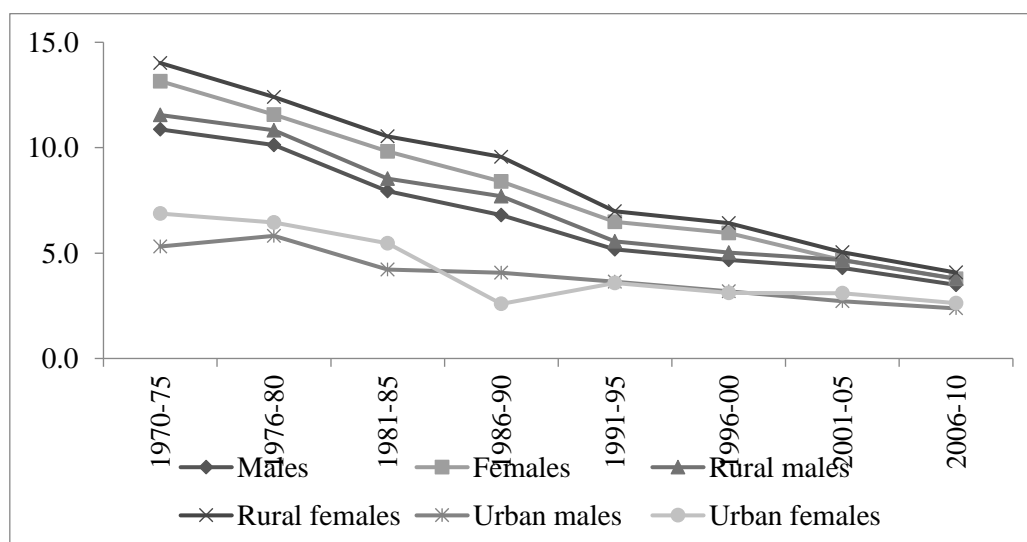
Figure 3 shows the trend in the maximum total expected longevity over time in India by sex and place of residence. An apparent rise in maximum expected longevity has been observed across all the population subgroups in India. The maximum increase has been observed for urban females in India. In 2006-10, the urban females had maximum expected longevity of 74.0 years. Overall, maximum total expected longevity in males had increased from 61.1 years in 1970-75 to 68.0 years in 2006-10 and in females from 61.8 years to 71.3 years during the similar period. The male-female gap in maximum expected longevity had increased over time in India. The male-female gap has increased more prominently in the rural than urban areas. Overall, the gap between the subgroups had not converged during this whole period 1970-2010. Comparing results from the previous chapters with this chapter suggests that the rate of increase in maximum expected longevity in India is slower than the life expectancy at birth.

Figure 3: Trend in Maximum Total Expected Longevity in India by Sex and Residence, 1970-2010



The higher expected longevity in 1970-75 was mainly because maximum remaining life expectancy was observed at higher ages. Over the period, the maximum values are getting close to age 0 as it can be viewed from the Figure 4. The absolute difference between maximum expected longevity and life expectancy at birth during 1970-75 was 10.9 years for males and 13.2 years for females in India. This clearly suggests that the maximum was achieved at much higher ages during 1970-75. These figures reduced to 3.5 years for males and females during 2006-10, which indicates that the absolute difference between maximum expected longevity and the life expectancy at birth had decreased considerably in India. The rate of decline in this difference was rapid among females than males in India. Among all the subgroups, the difference was highest among rural females (14.0 years) and lowest among urban males (5.3 years) during 1970-75. The gap between these four subgroups has reduced from 8.7 years in 1970-75 to 1.7 years in 2006-10. The trend implies that in the years to come maximum total expected longevity and the life expectancy at birth would be similar.

Figure 4: Trend in Absolute Difference between Maximum Total Expected Longevity and Life Expectancy at Birth in India by Sex and Residence, 1970-2010



Trend in Maximum Total Expected Longevity in Major States of India by Sex and Residence

Table 1 provides the estimates of the maximum total expected longevity of males in the major states of India from 1970-75 to 2006-10. The result shows that the maximum expected longevity had increased

from 1970-75 to 2006-10 in each and every major state of India. The highest absolute increase in maximum expected longevity was observed in Tamil Nadu (from 59.8 years in 1970-75 to 69.2 years in 2006-10) followed by Rajasthan (8.8 years increase) and Andhra Pradesh (8.4 years increase). The minimum increase has been observed in Haryana (1.9 years) and Punjab (2.7 years). Assam is the state where the maximum expected longevity remains the lowest in every time period. The absolute increase in maximum expected longevity was more in the time period of 1970s and 1980s till 1991-95 after which the rate of increase is becoming more or less stagnant. The interstate variation in maximum expected longevity of males has not decreased in India. The difference between maximum and minimum value at a given point of time remains more or less similar.

Table 1: Trend in Maximum Total Expected Longevity of Males in Major States of India, 1970-2010

	1970 -75	1976 -80	1981 -85	1986 -90	1991 -95	1996- 2000	2001 -05	2006 -10
Andhra Pradesh	58.5	60.4	63.0	63.6	64.5	65.3	67.0	66.9
Assam	57.2	58.8	59.2	60.7	62.5	63.2	63.8	64.8
Bihar*	-	-	63.0	63.4	64.9	65.8	68.2	68.6
Gujarat	61.1	61.9	63.2	63.7	64.5	67.0	67.7	68.3
Haryana	66.9	66.2	66.2	67.0	66.4	68.9	69.3	68.8
Himachal Pradesh	63.9	64.2	65.1	67.9	68.1	70.0	71.2	70.8
Karnataka	62.5	62.2	65.5	65.2	65.3	66.6	67.9	67.9
Kerala	65.5	66.3	67.6	69.4	69.7	69.1	70.4	71.3
Madhya Pradesh	61.6	61.0	62.3	63.8	63.1	63.1	65.0	65.9
Maharashtra	62.1	62.4	63.6	65.5	67.4	67.4	69.0	69.9
Orissa	61.8	60.1	61.7	63.5	64.1	63.9	65.1	66.6
Punjab	67.1	69.8	67.6	69.6	68.8	69.1	70.8	69.8
Rajasthan	60.6	61.8	62.5	62.9	65.6	66.4	68.5	69.4
Tamil Nadu	59.8	62.4	62.4	64.3	65.3	66.6	68.5	69.2
Uttar Pradesh	60.7	61.3	62.3	63.0	64.5	65.1	66.2	66.1
West Bengal*	-	-	63.1	64.4	65.4	67.1	69.1	69.7

Note. *For 1970-75 and 1976-80 there is no life table for Bihar and West Bengal.

Table 2 shows the trend in maximum total expected longevity of females in major states of India. Maximum expected longevity of females had improved unanimously in India. Comparing results from Table 1 and 2 shows that the maximum expected longevity had increased more rapidly among females than males. The highest absolute increase in maximum expected longevity has been observed in Himachal Pradesh from 61.1 years in 1970-75 to 75.8 years in 2006-10. Females in more than five states namely Himachal Pradesh, Andhra Pradesh, Tamil Nadu, Assam, Orissa and Maharashtra had experienced more than 10 years gain in maximum expected longevity in this time period. For males, the maximum increase that has been observed was 9.4 years for Tamil Nadu. Within the state, the maximum expected longevity of females was higher than males during most of the period. The minimum increase was observed for Punjab (5.7 years) followed by Madhya Pradesh (7.8 years) and Bihar (7.9 years). The pace of increase in maximum expected longevity was more or less the same till 2001-05. The increase was minimum from 2001-05 to 2006-10 as compared to the other time periods. Similar to what observed in males, the interstate variation in maximum expected longevity has not decreased much even among females in India.

Table 2: Trend in Maximum Total Expected Longevity of Females in Major States of India, 1970-2010

	1970 -75	1976 -80	1981 -85	1986 -90	1991 -95	1996- 2000	2001 -05	2006 -10
Andhra Pradesh	59.1	63.0	65.7	66.5	67.1	68.9	71.7	71.9

Assam	54.8	58.3	59.9	61.9	62.6	63.8	65.7	67.4
Bihar*	-	-	61.4	62.8	63.4	65.8	68.5	69.3
Gujarat	63.6	63.6	66.1	66.0	68.3	70.5	72.4	72.7
Haryana	66.0	65.7	66.6	68.5	69.7	71.4	74.0	74.3
Himachal Pradesh	61.1	62.9	67.7	70.7	70.3	73.4	75.4	75.8
Karnataka	62.8	64.1	67.3	68.9	68.3	70.4	72.8	72.7
Kerala	68.1	69.6	73.1	74.6	76.4	75.0	76.7	77.0
Madhya Pradesh	61.2	62.1	64.1	64.1	64.3	65.6	68.1	69.0
Maharashtra	63.7	65.1	66.9	70.1	68.2	71.2	72.9	73.9
Orissa	56.5	59.2	61.6	62.7	64.8	64.6	67.5	68.5
Punjab	68.7	72.3	70.4	73.3	71.1	72.4	74.9	74.4
Rajasthan	62.4	62.6	65.0	66.3	67.0	71.0	72.5	74.4
Tamil Nadu	59.2	62.1	63.8	66.9	67.7	69.6	71.8	73.1
Uttar Pradesh	60.4	61.6	62.6	63.9	65.3	66.2	68.2	69.6
West Bengal*	-	-	64.8	66.6	66.8	69.1	72.0	73.2

Note. *For 1970-75 and 1976-80 there is no life table for Bihar and West Bengal.

Results from Table 3 shows that the maximum expected longevity of males has increased in the similar manner in the rural areas as it was observed for the overall population. The highest absolute increase during the entire period in maximum expected longevity was observed in Tamil Nadu (10.3 years) followed by Rajasthan (8.6 years), Maharashtra (8.0 years) and Andhra Pradesh (8.1 years). The minimum increase was observed in Haryana (1.3 years) followed by Punjab (2.6 years), Madhya Pradesh (3.8 years) and Orissa (4.2 years). The highest gain in the maximum expected longevity in the rural areas was observed from 1970-75 to 1981-85, after which the rate of increase in maximum expected longevity remains very slow. The gap between the state with highest and the lowest maximum expected longevity has remained mostly the same during the entire period.

Table 3: Trend in Maximum Total Expected Longevity of Rural Males in Major States of India, 1970-2010

	1970 -75	1976 -80	1981 -85	1986 -90	1991 -95	1996- 2000	2001 -05	2006 -10
Andhra Pradesh	58.0	60.6	62.4	62.8	64.1	64.5	66.0	66.1
Assam	56.7	58.4	58.7	60.4	62.1	62.6	63.2	64.0
Bihar*	-	-	62.7	63.2	64.6	65.4	67.9	68.5
Gujarat	60.5	61.6	62.3	63.7	64.0	66.1	66.8	66.7
Haryana	66.6	62.9	65.3	66.3	66.1	68.8	69.4	67.9
Himachal Pradesh	63.7	64.1	64.9	68.1	67.9	70.0	71.2	70.4
Karnataka	62.2	61.9	63.8	65.6	64.2	65.5	67.2	66.3
Kerala	65.7	66.4	68.2	69.2	69.4	68.8	70.4	71.1
Madhya Pradesh	61.1	60.5	62.7	63.5	62.5	63.6	64.2	64.9
Maharashtra	61.2	60.9	64.0	64.8	65.9	66.4	67.8	69.2
Orissa	62.1	59.8	61.4	63.3	63.6	63.5	64.6	66.3
Punjab	66.6	69.7	66.7	68.3	68.9	68.7	70.8	69.2
Rajasthan	60.7	61.3	62.0	63.1	64.9	67.0	68.4	69.3
Tamil Nadu	57.8	61.2	61.3	63.2	64.3	65.6	67.4	68.1
Uttar Pradesh	60.4	62.0	61.9	62.5	64.1	65.8	65.6	65.8
West Bengal*	-	-	61.8	63.3	64.2	66.4	68.1	69.1

Note. *For 1970-75 and 1976-80 there is no life table for Bihar and West Bengal.

Table 4 shows the trend in maximum total expected longevity of rural females in major states of India from 1970-75 to 2006-10. The results show that the maximum expected longevity has increased more rapidly among rural females than males. As compared to the overall females, the increase during the entire period in rural females was higher in many states. The maximum difference was observed for Rajasthan where the gain in maximum expected longevity among females was 12.0 years and in rural females this gain further increased to 13.4 years. Females from eight states observed more than 10 years gain in maximum expected longevity as compared to only one state for males. The highest absolute increase in maximum expected longevity was observed in Himachal Pradesh (14.9 years). The minimum increase was observed in Punjab (4.8 years) followed by West Bengal (5.8 years). Within each state, the male-female difference in maximum expected longevity was large in the rural areas. The maximum difference was observed in Himachal Pradesh. The male-female difference in maximum expected longevity for Himachal Pradesh was more than five years. The pace of increase in maximum expected longevity was highest in the time period of 1976-80 to 1981-85. Though the increase in maximum expected longevity was highest in the rural females, but the interstate variation also remains the largest. The difference between maximum and minimum value of the state was more than 10 years in 2006-10.

Table 4: Trend in Maximum Total Expected Longevity of Rural Females in Major States of India, 1970-2010

	1970-75	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-05	2006-10
Andhra Pradesh	59.1	62.3	64.6	65.4	66.5	68.1	71.2	71.3
Assam	54.2	57.6	59.1	61.8	61.8	63.0	64.9	66.5
Bihar*	-	-	62.0	62.2	63.9	65.5	68.2	69.1
Gujarat	62.9	63.5	65.4	65.3	68.2	71.1	71.8	71.8
Haryana	65.2	64.8	65.5	67.8	69.1	71.1	74.1	74.4
Himachal Pradesh	60.9	62.6	67.5	71.2	70.3	73.5	75.5	75.8
Karnataka	61.0	62.3	67.0	68.3	67.6	68.8	72.0	71.4
Kerala	68.1	70.1	72.7	74.1	77.3	74.9	76.8	78.1
Madhya Pradesh	60.5	61.2	63.3	64.3	63.6	65.1	67.2	68.1
Maharashtra	63.7	63.5	65.9	68.3	67.6	69.7	72.2	73.3
Orissa	56.0	58.8	61.4	63.2	64.1	64.2	67.0	67.9
Punjab	68.8	71.4	69.8	72.8	70.8	72.5	75.1	73.6
Rajasthan	61.2	62.0	64.3	65.8	65.1	70.8	72.4	74.6
Tamil Nadu	57.8	60.5	63.5	65.2	65.8	68.4	70.4	71.9
Uttar Pradesh	60.0	61.3	61.8	64.0	65.1	65.8	67.8	69.1
West Bengal*	-	-	64.0	65.7	65.6	68.4	71.1	69.8

Note. *For 1970-75 and 1976-80 there is no life table for Bihar and West Bengal.

Table 5 shows the trend in maximum total expected longevity of urban males in major states of India. The result shows that the maximum total expected longevity had increased considerably among the urban males in these major states. The highest absolute increase in maximum expected longevity was observed in Kerala (9.3 years), Andhra Pradesh (8.7 years) and Himachal Pradesh (8.4 years). The minimum increase was observed in Haryana (2.4 years), Punjab and West Bengal (4.7 years). As compared to the rural males, the gain in maximum expected longevity was more in the urban areas. The urban-rural difference in the absolute increase was more than three years for Kerala, Tamil Nadu and Orissa. The pace of increase in maximum expected longevity was maximum in the time period of 1970-75 to 1976-80.

Table 5: Trend in Maximum Total Expected Longevity of Urban Males in Major States of India, 1970-2010

	1970-75	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-05	2006-10
Andhra Pradesh	60.6	63.2	64.5	64.6	65.7	68.0	70.1	69.3
Assam	62.0	64.5	64.2	64.9	67.3	68.2	68.1	69.3
Bihar*	-	-	64.7	65.1	68.2	68.9	70.9	69.5
Gujarat	63.5	62.3	63.2	63.0	64.7	69.0	68.6	71.0
Haryana	68.2	64.7	68.3	67.1	68.7	69.1	69.0	70.6
Himachal Pradesh	66.1	68.0	68.2	66.2	70.2	71.3	72.6	74.5
Karnataka	64.9	65.1	67.0	66.3	67.9	69.1	69.9	70.7
Kerala	62.9	65.3	66.8	66.6	69.1	71.2	72.6	72.2
Madhya Pradesh	63.4	69.9	64.8	64.8	65.2	66.4	68.5	70.3
Maharashtra	63.8	64.9	65.4	67.1	70.9	69.7	69.4	71.1
Orissa	61.0	62.3	63.9	65.6	67.3	67.4	68.6	69.0
Punjab	66.8	67.8	71.2	68.4	68.9	70.7	70.8	71.5
Rajasthan	65.1	63.6	65.2	69.7	68.4	68.5	69.7	71.1
Tamil Nadu	64.2	64.4	64.7	65.7	67.6	68.9	70.5	70.9
Uttar Pradesh	62.4	63.8	64.7	63.7	65.3	66.7	68.9	68.2
West Bengal*	-	-	66.7	67.1	68.4	69.0	71.7	71.4

Note. *For 1970-75 and 1976-80 there is no life table for Bihar and West Bengal.

Table 6 shows the trend of the maximum total expected longevity of urban females in major states of India. The highest absolute increase from 1970-75 to 2006-10 in maximum expected longevity has been observed in Assam (11.6 years) and Gujarat (10.5 years). The minimum increase has been observed in Haryana (4.9 years) and Himachal Pradesh (5.9 years). The maximum expected longevity during 2006-10 was highest among urban females in major states of India as observed from the last column of Table 1-6. Within the state, the difference between male-female maximum total expected longevity remains very low in the urban than rural areas. This may be because of the fact that maximum expected longevity were already at higher levels for both males and females in the urban areas. The male-female difference in the total absolute gain was approximately three years in four states namely Assam, Tamil Nadu, Uttar Pradesh and Punjab. The pace of increase in maximum expected longevity was maximum in the time period of 1970-75 to 1976-80.

Comparing the results from Table 4 and 6 shows that the maximum expected longevity has increased more rapidly among the rural females in these major states than the urban females. For instance, the total increase in expected longevity of females from rural Rajasthan during the entire period was 13.4 years and for the urban females was 8.0 years. The difference between the maximum and minimum value of maximum expected longevity of urban females in 1970-75 was 10 years that reduced to 6.6 years in 2006-10.

Table 6: Trend in Maximum Total Expected Longevity of Urban Females in Major States of India from 1970-75 to 2006-10

	1970 -75	1976 -80	1981 -85	1986 -90	1991 -95	1996- 2000	2001 -05	2006 -10
Andhra Pradesh	64.0	65.5	67.3	67.9	69.0	71.7	73.5	73.2
Assam	62.1	69.0	64.9	66.2	68.7	71.4	72.9	73.7
Bihar*	-	-	64.6	65.9	69.4	69.5	71.9	71.7
Gujarat	65.5	64.2	66.8	67.8	67.8	71.8	75.3	76.0
Haryana	69.8	67.6	69.3	71.1	72.5	72.7	73.8	74.7
Himachal Pradesh	72.2	68.7	69.6	67.5	71.0	74.8	74.6	78.1
Karnataka	69.2	69.1	70.3	69.4	70.8	75.0	74.6	75.3
Kerala	68.4	69.7	72.3	72.3	77.9	76.6	77.1	77.7
Madhya Pradesh	65.5	66.0	66.3	67.9	66.6	68.0	71.5	72.7
Maharashtra	65.8	68.3	80.7	70.5	70.5	74.4	74.7	75.1
Orissa	63.9	64.7	66.5	66.2	68.7	69.0	72.6	72.6
Punjab	68.3	71.7	73.3	75.0	71.2	72.8	75.3	76.6
Rajasthan	65.9	65.6	67.2	67.5	70.6	71.9	74.3	73.9
Tamil Nadu	65.5	65.2	67.4	68.2	71.9	72.5	74.7	75.3
Uttar Pradesh	62.5	62.8	64.7	66.7	67.3	68.4	69.3	71.5
West Bengal*	-	-	68.6	68.2	71.3	71.6	74.7	74.8

Note. *For 1970-75 and 1976-80 there is no life table for Bihar and West Bengal.

Record Maximum Expected Longevity and Record Maximum Remaining Life Expectancy in India by Sex and Residence

Table 7 shows that the record expected longevity was achieved by Punjab and Haryana in the time period of 1970-75 to 1976-80. From 1981-85 to 2006-10, females in Kerala have the record expected longevity. Overall, a larger proportion of record longevity was held by Kerala. The state with record longevity for males changed from one time period to another. In 2006-10, Kerala and Himachal Pradesh had the record expected longevity for males. The record expected longevity in the urban areas was higher than the rural areas. The maximum record longevity in the urban areas was observed in Himachal Pradesh. The increase in record longevity among males was very slow as compared to females. For example, males record longevity increased from 67.1 years in 1970-75 to 71.3 years in 2006-10 and for females the increase was from 68.7 to 77.0 years.

Table 8 shows that the record maximum remaining life expectancy was observed in Punjab, Haryana and Kerala in the time period of 1970-75 to 1986-90. From 1991-95 to 2006-10 Kerala hold the record maximum remaining life expectancy. Notably, in recent years Kerala mostly hold the record for the remaining life expectancy in every population subgroup from 1991-95, except Himachal Pradesh, Maharashtra and Himachal Pradesh appearance at some point in time during the entire period 1991-2010. Overall, males record remaining life expectancy increased from 65.1 years in 1970-75 to 71.3 years in 2006-10 and females record remaining life expectancy increased from 66.1 to 77.0 years. From the comparison of Table 7.8 and 7.9, it is evident that the difference between the record remaining life expectancy and record expected longevity had decreased.

Table 7: Record Maximum Total Expected Longevity by Sex and Residence, 1970-2010

Time			Record longevity	State which has achieved record maximum total expected longevity
1970-75	Females	Overall	68.7	Punjab
		Rural	68.8	Punjab
		Urban	72.2	Himachal Pradesh
	Males	Overall	67.1	Punjab
		Rural	66.6	Haryana
		Urban	68.2	Haryana
1976-80	Female	Overall	72.3	Punjab
		Rural	71.4	Punjab
		Urban	71.7	Punjab
	Male	Overall	69.8	Punjab
		Rural	69.7	Punjab
		Urban	69.9	Madhya Pradesh
1981-85	Females	Overall	73.1	Kerala
		Rural	72.7	Kerala
		Urban	80.7	Maharashtra
	Males	Overall	67.6	Punjab
		Rural	68.2	Kerala
		Urban	71.2	Punjab
1986-90	Females	Overall	74.6	Kerala
		Rural	74.1	Kerala
		Urban	75.0	Punjab
	Males	Overall	69.6	Punjab
		Rural	69.2	Kerala
		Urban	69.7	Rajasthan
1991-95	Females	Overall	76.4	Kerala
		Rural	77.3	Kerala
		Urban	77.9	Kerala
	Males	Overall	69.7	Kerala
		Rural	69.4	Kerala
		Urban	70.9	Maharashtra
1996-00	Females	Overall	75.0	Kerala
		Rural	74.9	Kerala
		Urban	76.6	Kerala
	Males	Overall	70.0	Himachal Pradesh
		Rural	70.0	Himachal Pradesh
		Urban	71.3	Himachal Pradesh
2001-05	Females	Overall	76.7	Kerala
		Rural	76.8	Kerala
		Urban	77.1	Kerala
	Males	Overall	71.2	Himachal Pradesh
		Rural	71.2	Himachal Pradesh
		Urban	72.6	Himachal Pradesh
2006-10	Females	Overall	77.0	Kerala
		Rural	78.1	Kerala
		Urban	78.1	Himachal Pradesh
	Males	Overall	71.3	Kerala
		Rural	71.1	Kerala
		Urban	74.5	Himachal Pradesh

Table 8: Record Maximum Remaining Life Expectancy by Sex and Residence, 1970-2010

Time			Maximum remaining life expectancy	State which has achieved record maximum remaining life expectancy
1970-75	Females	Overall	66.1	Punjab
		Rural	66.1	Kerala
		Urban	70.2	Himachal Pradesh
	Males	Overall	65.1	Punjab
		Rural	64.6	Haryana, Punjab
		Urban	66.2	Haryana
1976-80	Female	Overall	69.3	Punjab
		Rural	69.1	Kerala
		Urban	69.7	Punjab
	Male	Overall	67.8	Punjab
		Rural	67.7	Punjab
		Urban	67.9	Madhya Pradesh
1981-85	Females	Overall	72.1	Kerala
		Rural	71.7	Kerala
		Urban	78.7	Maharashtra
	Males	Overall	66.6	Punjab, Kerala
		Rural	67.2	Kerala
		Urban	70.2	Punjab
1986-90	Females	Overall	73.6	Kerala
		Rural	73.1	Kerala
		Urban	73.0	Punjab
	Males	Overall	68.6	Punjab
		Rural	68.2	Kerala
		Urban	67.7	Rajasthan
1991-95	Females	Overall	75.4	Kerala
		Rural	76.3	Kerala
		Urban	77.9	Kerala
	Males	Overall	68.7	Kerala
		Rural	68.4	Kerala
		Urban	69.9	Maharashtra
1996-00	Females	Overall	75.0	Kerala
		Rural	74.9	Kerala
		Urban	75.6	Kerala
	Males	Overall	69.1	Kerala
		Rural	69.0	Himachal Pradesh
		Urban	70.3	Kerala, Himachal Pradesh
2001-05	Females	Overall	76.7	Kerala
		Rural	76.8	Kerala
		Urban	77.1	Kerala
	Males	Overall	70.4	Kerala
		Rural	70.4	Kerala
		Urban	71.6	Kerala, Himachal Pradesh
2006-10	Females	Overall	77.0	Kerala
		Rural	77.1	Kerala
		Urban	77.7	Kerala
	Males	Overall	71.3	Kerala
		Rural	71.1	Kerala
		Urban	73.5	Himachal Pradesh

Relationship of Maximum Remaining Life Expectancy and Life Expectancy at Birth

Figure 5 to 10 shows the relationship between maximum remaining life expectancy at the age where it has been achieved and the life expectancy at birth. The shape of each data point signifies the age at which the maximum remaining life expectancy has been achieved. With the improvement in the life expectancy at birth, the maximum remaining life expectancy had also increased in India. The graphs also show the convergence between maximum remaining life expectancy and the life expectancy at birth occurred at higher values of the life expectancy at birth. In the developed countries, the occurrence of this convergence mostly started during 1970s and when the life expectancy at birth gets closer to 70 years (Romo & Engelman, 2009). In India, the maximum remaining life expectancy usually occurred at age 4 and 5 for the lower life expectancy at birth values. It goes downwards to age 0 and 1 when the life expectancy at birth reached higher values. It's apparent from the Figure 7.5 to 7.10 that the maximum remaining life expectancy at age 0 and 1 occurred subsequent to the life expectancy at birth crossing 60 years mark. These higher life expectancy values are generally for the recent period. By place of residence, it can be seen that the maximum remaining life expectancy had always been closer to the life expectancy at birth in the urban than the rural areas. The maximum remaining life expectancy has often been achieved at age 4 or 5 in the rural areas and in the urban areas at age 2 or 3. There has been more variation in the values of the maximum remaining life expectancy and the life expectancy at birth in the rural areas and females than their counter parts.

Figure 5: Life Expectancy at Birth and Maximum Remaining Life Expectancy by Age at which Achieved for Males in Major States of India, 1970-2010

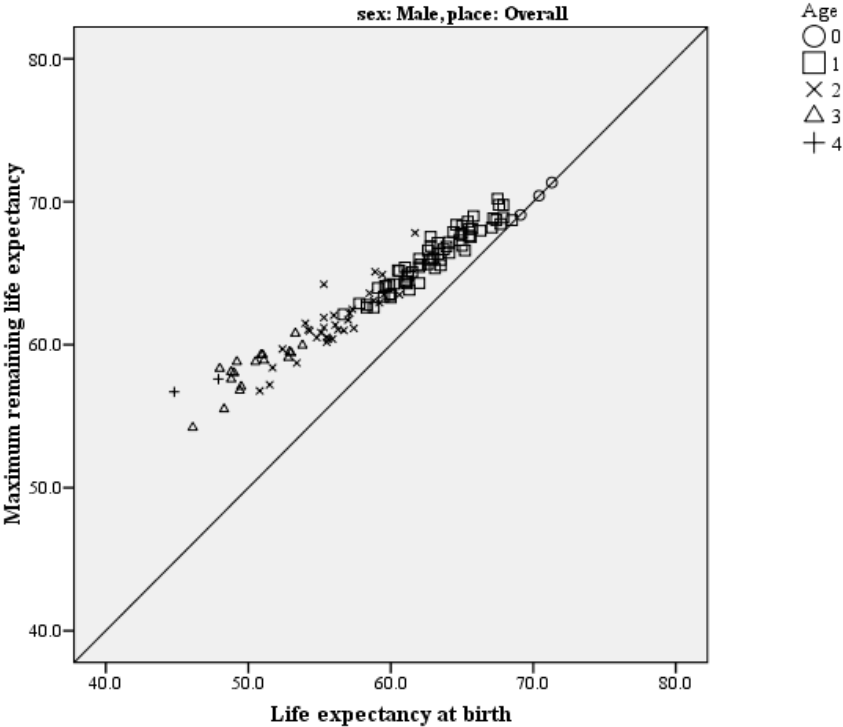


Figure 6: Life Expectancy at Birth and Maximum Remaining Life Expectancy by Age at which Achieved for Females in Major States of India, 1970-2010

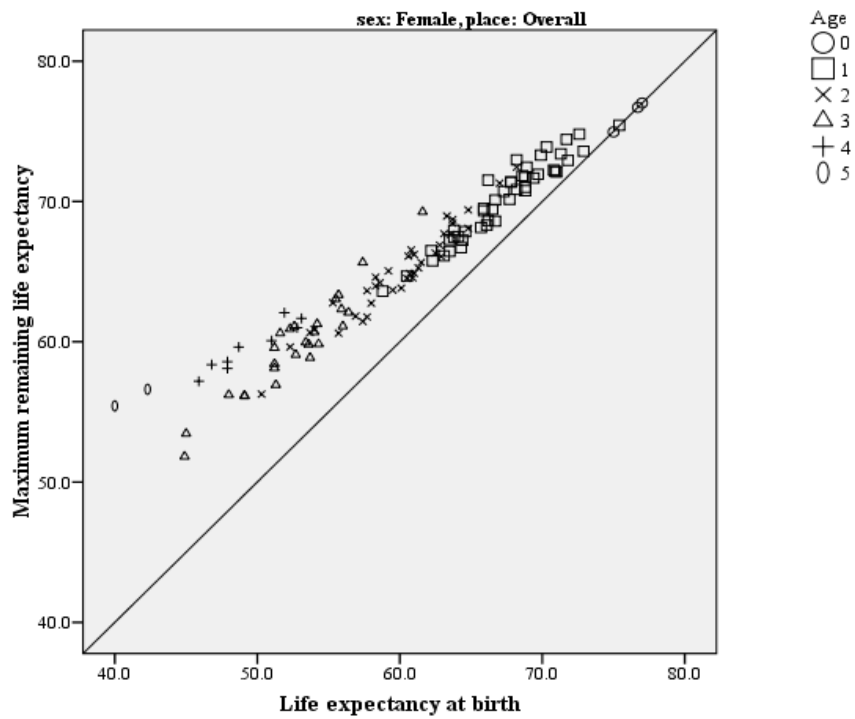


Figure 7: Life Expectancy at Birth and Maximum Remaining Life Expectancy by Age at which Achieved for Rural Males in Major States of India, 1970-2010

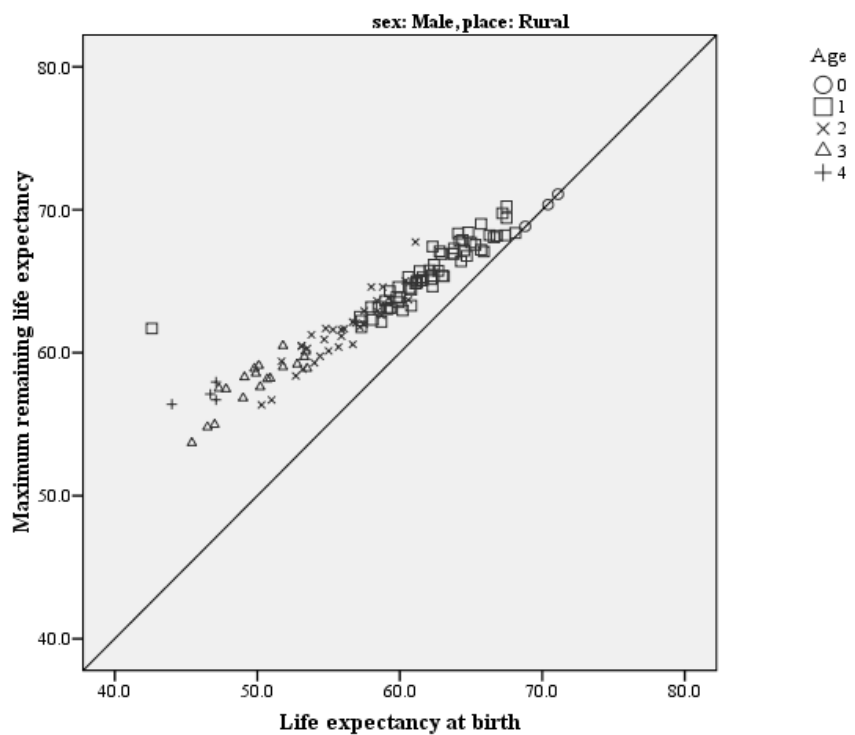


Figure 8: Life Expectancy at Birth and Maximum Remaining Life Expectancy by Age at which Achieved for Rural Females in Major States of India, 1970-2010

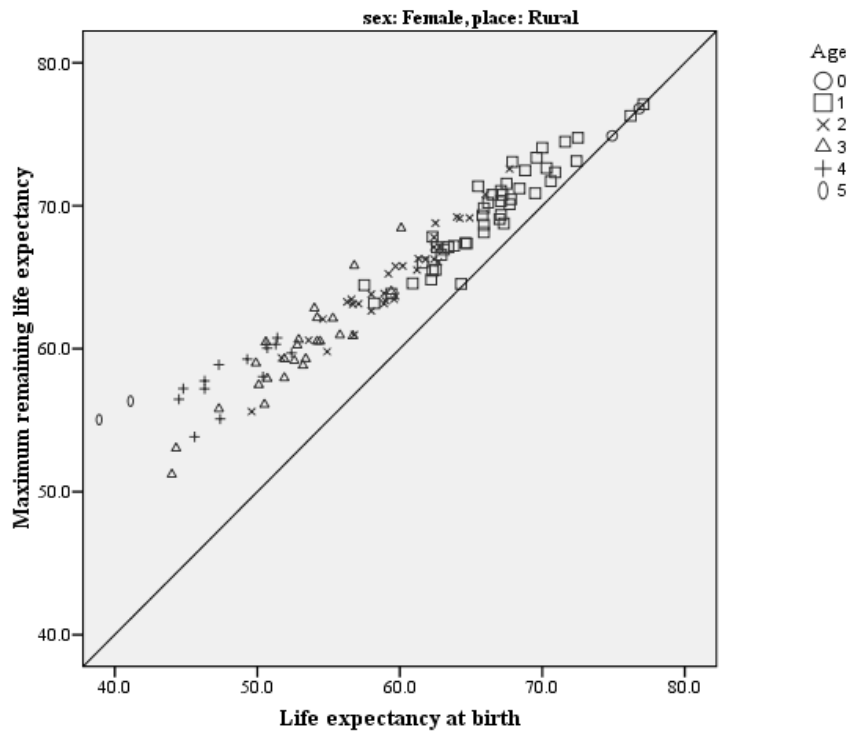


Figure 9: Life Expectancy at Birth and Maximum Remaining Life Expectancy by Age at which Achieved for Urban Males in Major States of India, 1970-2010

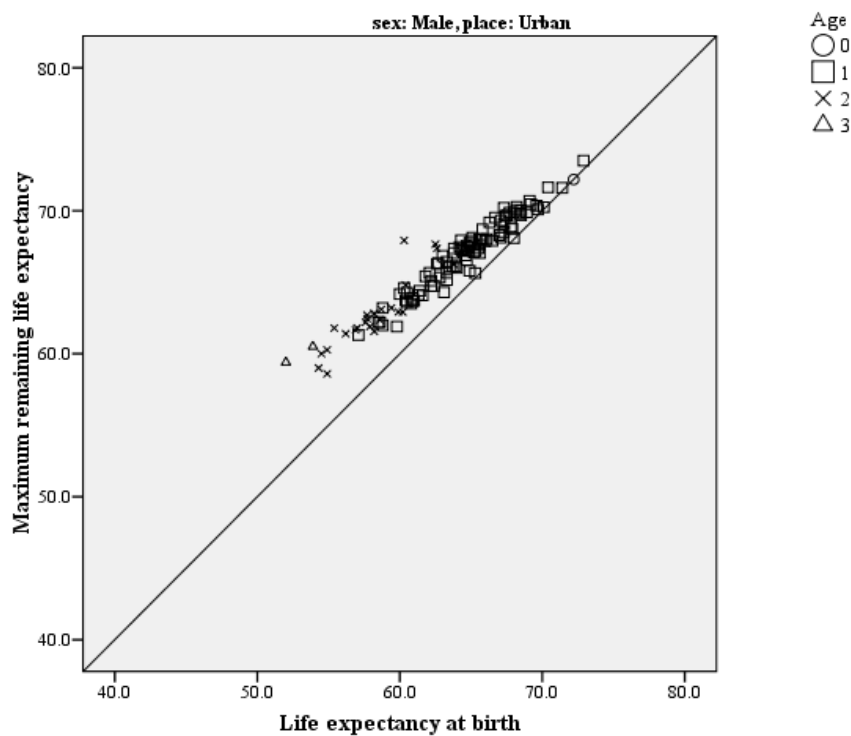
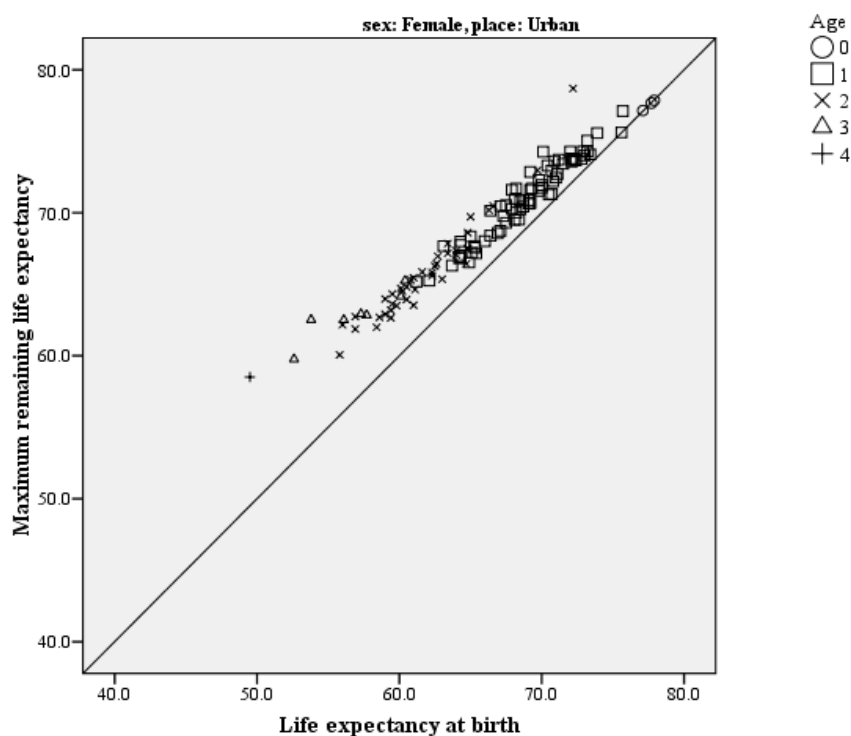


Figure 10: Life Expectancy at Birth and Maximum Remaining Life Expectancy by Age at which Achieved for Urban Females in Major States of India, 1970-2010



4. Summary and Discussion

The largest gain in expected longevity trends is observed in the initial ages. At the older ages, the rise in expected longevity remains steeper. The maximum expected longevity had increased significantly in India for every population group. The total gain in the maximum expected longevity from 1970-75 to 2006-10 was higher for females than males. A similar phenomenon has also been observed for the increase in the life expectancy at birth (Chaurasia, 2010). Comparing results from the previous papers, this study suggests that the pace of increase in maximum expected longevity in India was slower than the life expectancy at birth and life disparity. It has been found in another study for the large number of countries that the increase in maximum expected longevity is much slower than the life expectancy at birth (Romo & Engelman, 2009). Among all the four population subgroups: rural males, rural females, urban males and urban females, urban females had the highest value for the maximum expected longevity. This finding remains similar within the major states of India.

Improvement in maximum expected longevity has been observed over time in each and every state. Females in many of the major states have experienced a phenomenal increase in expected longevity. However, the difference in maximum total expected longevity between the states had not reduced in the similar way as it was observed for the other life expectancy indicators. The difference between the states for the other mortality indicators such as life expectancy at birth or the temporary life expectancy had reduced over time in India (Chaurasia, 2010; Saikia et al., 2011). Within the state, the male-female gap in maximum expected longevity was higher in the rural than urban areas. This can be attributed to the fact that males and females in the urban areas previously had much higher longevity.

The gain in the maximum expected longevity in Uttar Pradesh in absolute terms cannot be compared with the gain in life expectancy at birth. This was mainly because of the large difference in maximum total expected longevity and the life expectancy at birth in Uttar Pradesh during 1970s and 1980s. Punjab and Haryana are the states observed the lowest gain in expected longevity. These two states have even observed the slower rate of decline in life table entropy as found in another study (Chaurasia, 2010). The states which have achieved record maximum expected longevity or record of maximum remaining life expectancy during any period from 1970-2010 are five or six states. Though, Kerala is the most appeared state still there were states such as Maharashtra, Himachal Pradesh, Punjab and Haryana,

which have achieved the record expected longevity at some point of time. Among females, Kerala mostly holds the record. Punjab and Haryana were the most observable states in 1970s and 1980s and during 1990s and 2000s Kerala remained the leader. Maximum expected longevity record was achieved by more than six states within this time period of 40 years among males.

Convergence between maximum remaining life expectancy and life expectancy at birth has been observed over time in India. With the improvement in life expectancy, age trend of remaining life expectancy becomes a monotonic decreasing function of age (Romo & Engelman, 2009). Kerala is the state where both values have become similar in the recent time period. Rural areas had achieved maximum remaining life expectancy at much higher age than urban areas showing a significant role of early age mortality in the rural areas. The convergence also suggests that more number of survivors can anticipate a longer life, which was possible earlier only when you surpass the mortality hazard of early age mortality.

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