# Inequality in length of life in India: an empirical analysis


## Abstract

***Background:*** Studies on inequality in length of life in India are limited. The study of inequality in length of life is necessary to assess the performance of societies or different sections of a society with respect to length of life.

***Objective:*** To examine the trends in inequality in length of life in India and 15 major states during the last three decades. Second, to estimate the contribution of mortality change in different age groups to the overall change in inequality in length of life in India and major states of India.

***Method:*** We estimate Gini coefficient, life disparity, and threshold age to examine the inequality. For estimating the afore-mentioned indicators, we first convert the abridged life tables for India and 15 major states into modelled complete life tables. We use Bessel spline interpolation to estimate the abridged life tables into modelled complete life tables ending at the age of 110. Finally, we decompose the change in Gini coefficient into contributions of mortality change in different age groups.

***Result:*** In Indian males, the life expectancy at birth increased by about 8 years between 1981 and 2011. The life disparity decreased by about 3.6 years and the threshold age increased by about 5.5 years during this period. In comparison, in India females, the life expectancy increased by about 12 years, the life disparity reduced by 5.2 years, and the threshold age increased by 7.2 years. The mortality changes in the age group 0-1 contributed maximum to the decline in Gini between 1981 and 2011 for males, females, and urban residents. Mortality change in the age group 1- 4 contributed maximum to the decline in Gini in rural residents.

***Conclusion:*** The changes in various measures of mortality pattern differ markedly between males and females, urban-rural residents, and states of India.

***Contribution:*** This study provides more reliable estimates of inequality in length of life in India and 15 major states since the estimation is done using complete life tables starting at age 0 and ending at age 110.


**Keywords:** inequality in length of life, Gini coefficient, life disparity, threshold age, decomposition of Gini by age

# Inequality in length of life in India: an empirical analysis

## Introduction

India has witnessed a dramatic improvement in life expectancy at birth since independence. The life expectancy at birth increased from 32-34 years in 1951 to 68 years in 2013 (Bhat 1998, 2000; RGI 2017). Although there is a dramatic improvement, the fruits of the improvement were not reaped equally by the different sections of the Indian society. For example, while the life expectancy at birth for females increased from 32-34 years in 1951 to 70 years in 2013, the life expectancy at birth for males increased from 32-34 years in 1951 to 68 years in 2013 (RGI 2017). Likewise, while the life expectancy at birth in urban areas increased from 62 years in 1981 to 72 years in 2013, the life expectancy in rural areas increased from about 55 years in 1981 to 67 years in 2013 (RGI 2017). Similarly, there are significant state and regional disparities regarding life expectancy at birth in India.

Studies dealing with mortality usually focus on average indicators such as life expectancy at birth, infant mortality rate, maternal mortality rate/ratio, etc. Average indicators, although, are good to monitor the country's/state's progress at the macro level, they hide wide socio-economic inequalities prevailing the population. For example, the infant mortality rate for India is 41 deaths per 1,000 live births. Significant variation in infant mortality rate is observed when we segregate the estimate by urban-rural residence. The infant mortality rate in rural India is 46 deaths per 1,000 live births. This compares with only 29 deaths per 1,000 live births in urban India (IIPS and ICF 2017). Interestingly, socio-economic inequalities tend to recede the improvements in average indicators. Hence, there is a pressing need to study socio-economic inequalities in mortality. Particularly, inequality analysis is necessary to assess the performance of societies or different sections of the societies regarding mortality.

A number of studies in the past have dealt with trends and differentials in length of life in India (James & Syamala, 2010; Saikia et al., 2011; Sauvaget et al., 2011; Singh & Ladusingh 2016a). However, there is limited evidence on the trends in inequality in length of life in India and states (Singh et al. 2017; Singh & Ladusingh 2016a, 2016b; Saikia et al. 2011). Saikia et al. (2011) revealed substantial reductions in inter-state inequality in temporary life expectancy between 1970-75 and 2000-04. Singh and Ladusingh (2016a) examined the sex differentials in life expectancy and life disparity in India and states. The sex differentials in life expectancy and life disparity were more pronounced in urban than in rural areas. Singh and Ladusingh (2016b) examined the trends in early life disparity in India. Singh et al. (2017) examined the trends in inequality in length of life in India and 15 major states. They used Gini coefficient to examine the trends in inequality in length of life. They further decomposed the decline in Gini coefficient to estimate the contribution of mortality change in different age groups to the decrease in Gini coefficient. While the mortality decline in the age group 0-1 contributed the maximum to the reduction in Gini coefficient between 1981 and 2011, the mortality decline in 60+ tended to increase the Gini coefficient.

Only the study by Singh et al. (2017) systematically examined the trends in inequality in length of life across all ages in India. Singh et al. (2017) used abridged life tables ending at age 70+ to estimate the trends in Gini coefficient for India and 15 major states during 1981-2011. Shkolnikov, Andrew and Begun (2003) have shown that the estimation of Gini coefficient using aggregated mortality rates at older ages rather than real mortality rates might get affected due to the increase in the proportion of deaths at older ages. Shkolnikov, Andrew and Begun (2003) have also shown that as the mortality rates in older ages increase it is necessary to use real mortality data for estimation of Gini coefficient. Having said that, we estimate the trend in Gini coefficient for India and 15 major states between 1981 and 2011 using modelled complete life tables. Besides, we also estimate trends in life disparity and threshold age for India and 15 major states. Life disparity is a dispersion measure. Life disparity is defined as average life years lost due to death (Vaupel, Zhang and Raalte 2011; Zhang and Vaupel 2009). Threshold age is the age which separates early deaths from late life deaths. Saving lives before threshold age compresses the life disparity whereas lives saved after threshold age expands the life disparity (Zhang and Vaupel 2009). Finally, we decompose the change in Gini coefficient between 1981 and 2011 to examine the contribution of mortality change in different age groups to the overall change in Gini coefficient between 1981 and 2011.

## Data and Methods

*Data*

Data from the Sample Registration System (SRS) is used for the period 1981-2011 to examine trends in inequality in length of life in India and 15 major states of India. Sample

Registration System (SRS) under the aegis of the Office of the Registrar-General of India (RGI) is the primary and continuous source of data on mortality and life tables for India and 16 major states. These states are Himachal Pradesh, Punjab, Haryana and Rajasthan (all from the north), Uttar Pradesh and Madhya Pradesh (from the central), Assam (from the Northeast), West Bengal, Odisha and Bihar (from the east), Gujarat and Maharashtra (from the west), and Andhra Pradesh, Karnataka, Kerala and Tamil Nadu (from the south). One of these 16 states, Himachal Pradesh, could not be included in the analysis as the data is deficient for Himachal Pradesh for the years 1980, 1981 and 1990. Hence, we restrict our analysis to India and 15 major states of India.

Sample Registration System is the only reliable source of data on mortality and life tables in India. The SRS is based on matching vital events recorded by enumerators as and when they occur in a representative sample of rural and urban units with those from a bi-annual retrospective survey by independent supervisors (RGI, 2013). It provides information on age-specific death rates in different age groups up to 70+ starting from the year 1970. The broad age group of 70+ was further disaggregated in 1995 to provide rates for the age group 70-74, 75-79, 80-84 and 85+ year age groups. Additionally, SRS provides abridged life table based on SRS data for five-year periods starting from 1970-75. However, Saikia, Singh & Ram (2010) pointed out inconsistencies in the age group 1-4. Hence, instead of borrowing life tables directly from the SRS, we constructed new abridged life tables using age-specific mortality rates obtained from the SRS.

*Quality of Indian data*

A number of studies in the past have investigated the quality of data collected in the SRS. A majority of these studies have reported the quality of data in the SRS as reliable (Roy and Lahiri 1988; National Commission on Population 2001; Mathers et al. 2005). Studies conducted by the Registrar General of India during the early- and mid- 1980s reported an omission rate between 2.5% and 3.3% for deaths at the national level (RGI 1985; RGI 1988). The omission rates for births were between 1.8% and 3.1% during the same period. Bhat (2002) also examined the quality of SRS data during the period 1971-91. While the completeness of death registration remained stable, at 95%, for males, the completeness of death registration for females declined from 91% in 1971-80 to 88% in 1981-1991. Unfortunately, there is no published study that gives the completeness of death registration in SRS for the recent period.

The completeness of death registration might also vary by age. Saikia et al. (2011) compared the infant mortality rates (urban, rural, and total) from SRS with those of National Family Health Survey (NFHS) 1992-93, NFHS 1998-99, and NFHS 2005-06 between 1981 and 2006. The levels of agreement between SRS and NFHS estimates were high. The analysis by Saikia et al. (2011) also suggested a higher coverage of infant deaths in SRS compared with the NFHS. Also, the coverage infant deaths across the states in SRS is reasonably high. Studies also suggest higher age misreporting in death records for older people. A study by Bhat (1995) showed that SRS reports small number people at older ages, particularly among females. Saikia et al. (2011), using the SRS data, also evaluated the relationship between mortality at younger adult and older ages using the Gompertz curve. They found some instances of age understatement and an undercount of older females in the SRS data. The studies cited above clearly indicate towards the plausibility and suitability of SRS data for studying the inequality in length of life in India and the 15 major states of India.

*Estimating modelled complete life table*

Existing studies have proposed a number of methods for estimating complete life tables from abridged life tables. Brass relational logit model, Heligman and Pollard eight-parameter model, Kostaki model, Bassel spline, and Flex spline are some of the most widely used methods (Bailli et al. 2005; Kostaki and Panousis 2001). We used all the five methods to estimate complete life tables using the abridged life tables. On the basis of comparative assessment (absolute, relative deviations and plots of estimated values against the observed values) of the performance of these methods (Kostaki and Panousis 2001), we decided to use Bessel spline for estimating complete life tables from abridged life tables (**Tables 1 and 2, and Figure 1**). The estimated values from Bessel spine fits less well than others during infancy but better over adulthood and older ages. On the contrary, the estimated values obtained from Heligman and Pollard eight-parameter model fitted better during early ages. The Bessel Spline interpolation is similar to cubic spline. The Bessel Spline differs from Cubic spline in that for Bessel spline cubics are chosen in such a way that only the first derivative is continuous at each X data point. The second derivative is, not in general, cubic. The key advantage of Bessel spline is that it gives local interpolation. This means that the (X,Y) values at any given data point only affects the interpolated curve near that point.

The modelled complete life tables started at age ‘0’ and ended at age ‘110’. We estimated the complete life tables for males and females and urban-rural residence for India and 15 major states.

*Estimation of Gini coefficient*

Gini coefficient typically measures the distribution of income across the share of population. Applying the similar framework to the mortality-by-age schedules, Gini coefficient can be estimated using complete life tables. The person-years lived from birth to death may be treated as cumulative income and the cumulative number of deaths may be treated as the population share (Shkolnikov, Andrew and Begun 2003). The coefficient varies from ‘0’ to ‘1’. It is equal to 0 if all people die at the same age and 1 if all individuals die at age ‘0’ and one individual dies at an infinitely old age. Greater or lower values of Gini coefficient show a greater or lower magnitude of interindividual differences in length of life.

*Decomposition of Gini coefficient by age groups*

We used the formula developed by Shkolnikov, Andrew and Begun (2003) to decompose the change in Gini coefficient into the contribution of mortality change in different age groups.

*Estimation of life disparity*

Life disparity is defined as average life years lost due to death (Vaupel, Zhang and Raalte 2011; Zhang and Vaupel 2009). Life disparity narrows when lives are saved at ‘early’ ages and widens when lives are saved at ‘late’ ages (Vaupel, Zhang & Raalte 2011; Zhang and Vaupel 2009). While saving lives at ‘early’ ages compresses the distribution of lifespan, saving lives at ‘late’ ages expands the distribution.

*Estimation of threshold age*

Threshold age is the age that separates deaths at ‘early’ ages from deaths at ‘late’ ages (Vaupel, Zhang & Raalte 2011). Deaths occurring below threshold age are sometimes called ‘premature’ deaths, while those occurring after this age are called ‘late’ deaths.

## Results

**Figure 2** presents the trends in Gini coefficients for males and females. At the national level, the Gini coefficient for males declined from 21.3 in 1981 to 14.3 in 2011. The Gini coefficient also declined in all the major states although the pace of decline was different in different states. Among the major states, Gini coefficient in 2011 was highest for Uttar Pradesh followed by Odisha, Madhya Pradesh, and Andhra Pradesh. The maximum decline in Gini coefficient between 1981 and 2011 was noted in Rajasthan, Madhya Pradesh, Uttar Pradesh, and Bihar. In comparison, the Gini coefficient for females declined from 22.5 to 12.8 during the same period. The Gini coefficient for females also declined between 1981 and 2011 in all the major states of India. In 2011, the Gini coefficient was highest in Assam. Assam was followed by Uttar Pradesh and Madhya Pradesh. The maximum decline was observed in Uttar Pradesh. Uttar Pradesh is followed by Madhya Pradesh, Rajasthan, Bihar, and Assam regarding decline in Gini coefficient. Indeed, the Gini coefficient for males is higher compared with females in all states except Assam and West Bengal. In general, the Gini coefficient is considerably higher in central Indian states and Assam compared with the south Indian states.

**Figure 3** presents the trends in Gini coefficient for urban and rural residents. The Gini coefficient in urban areas declined from 17.2 in 1981 to 12.0 in 2011. Likewise, the Gini coefficient in rural areas declined from 22.7 in 1981 to 14.3 in 2011. The Gini coefficient declined in all the selected states in both urban and rural areas. The Gini coefficient was consistently higher in rural than in urban India.

**Table 3** shows the trends in life expectancy at birth, life disparity and threshold age for males for India and 15 major states of India. At the national level, the life expectancy at birth increased from 56 years in 1981 to 64 years in 2011. The life disparity during this period declined from 16 to 13. Interestingly, the threshold age increased from 58 years 64 years. In comparison, the life expectancy at birth for females increased from 56 years in 1981 to 67 years in 2011 (**Table 4**). The life disparity declined from 17 years to 12 years. The threshold age increased from 60 years to 67 years. Interesting results emerge when we compare the increase in life expectancy, decline in life disparity, and increase in threshold age for males and females. For males, the life expectancy increased by 8 years during 1981-2011. The life disparity declined by 3.6 years and the threshold age increased by 5.5 years. In comparison, the life expectancy for females increased by 12 years, the life disparity declined by 5.2 years, and the threshold age increased by 7.2 years. This pattern is similar in all the 15 major states of India. State-wide variations in trends in life expectancy, life disparity and threshold age were marked for both males and females. For example, the life expectancy for Kerala male was 63 years in 1981. The same for Uttar Pradesh was only 54 years. The life disparity for Kerala males was 13.1 years, while that for Uttar Pradesh male was 19.3 years. The threshold age for Kerala male was 62.2 years, while that for Uttar Pradesh male was 55.8 years. Similar patterns are observed for Kerala and Uttar Pradesh males in 2011. A similar pattern is observed for Kerala females and Uttar Pradesh females. Geographic patterns are also evident. South Indian states are far more egalitarian compared with the central and northeastern states regarding mortality for both males and females.

**Tables 5 & 6** show the trends in life expectancy at birth, life disparity and threshold age for urban and rural areas of India and 15 major states of India. The life expectancy at birth in urban India increased by 6 years between 1981 and 2011. The life disparity decreased by 3.4 years, while the threshold age increased by 5.4 years. On the contrary, the life expectancy in rural India increased by 10 years during this period. The life disparity decreased by 4.2 years and the threshold age increased by 6.5 years. These findings indeed suggest that the urban-rural gap in life expectancy, life disparity, and threshold age is narrowing in India over the last three decades. Compared with rural India, the urban India is still slightly more egalitarian regarding mortality. State-wide variations in trends in life expectancy, life disparity, and threshold age were marked for both urban and rural areas.

The age-specific contributions to the decrease in Gini coefficient for males and females between 1981 and 2011 are shown in **Figure 4**. At the all India level, the mortality decline in the age group 0-1 years contributed 81% to the decline in Gini coefficient for males. Furthermore, the mortality decline in the age group 1-4 years reduced the Gini coefficient by 37%. For females, the mortality decline in the age group 0-1 years contributed to 56% of the decline in Gini coefficient. The mortality decline in the age group 1-4 further reduced the Gini coefficient by 27%. Interestingly, the mortality decline in 60+ contributed 39% and 19% increase in Gini coefficient for males and females during 1981-2011 respectively. The state-wide variations in the age-specific contributions to the decline in Gini coefficient were marked.

The age-specific contributions to the decrease in Gini coefficient for urban and rural areas between 1981 and 2011 are shown in **Figure 5**. In urban areas, reduction in mortality in the age group 0-1 contributed 58% to the total decrease in Gini coefficient. The mortality decline in the age group 1-4 further reduced the Gini coefficient by 56%. Likewise, in rural areas, reduction in mortality in the age group 0-1 contributed 72% to total decrement in Gini coefficient. Furthermore, reduction of mortality in the age group 1-4 contributed 76% to the total decrement in Gini coefficient. However, mortality decline in age group 60+ tended to increase the Gini coefficient by 70% and 43% for rural and urban area respectively. The state-wide variations in age-specific contributions to decrease in Gini coefficient were marked.

## Discussion

The above analysis shows the trends in Gini coefficient for Indian males and females during 1981 and 2011. This study also explored the differentials in Gini coefficient between rural and urban areas of India and major states during the same period. Findings suggest a consistent decline in Gini coefficient for both males and females and urban-rural residents in India. Results also suggest declines in Gini coefficient for all the sub-groups of the population in different states of India. These findings are consistent with the findings of Singh et al. (2017). Although the trends and their interpretations remain same, the magnitude of Gini coefficients in our study differs from the estimates reported in Singh et al. (2017). The estimated values of Gini coefficient in Singh et al. (2017) is higher than those reported in our study for both males and females. The difference in the magnitude of Gini coefficients between the two studies is due to the type of life table used in the two studies. Singh et al. (2017) used abridged life table with the open age group as 70+ to estimate the Gini coefficient. In contrast, our study uses complete life table with the terminal age as 110. Estimation of Gini coefficient using complete life table is more robust than the estimation of Gini coefficient using abridged life table ending at an early age like 70+ (Shkolnikov, Andrew and Begun 2003). Our findings also suggest that the mortality decline in infancy and early childhood has led to the equalization of age at death in India and the 15 major states considered in the analysis. The scenario is opposite when we look at the contribution of mortality decline in older ages to the change in Gini coefficient. The mortality decline in the older ages (60+) tended to increase the Gini coefficient.

We also estimated the life disparity and threshold age to examine the inequality in length of life in more detail. The states or the population sub-groups that were better regarding life expectancy were also the ones who were more egalitarian regarding mortality. For example, among the 15 major states, Kerala having the highest life expectancy at birth in 2011 also had the least life disparity and the highest threshold age for both males and females. High negative correlations between high life expectancy and low life disparity have been found in several developed countries including the USA (Shkolnikov, Andrew and Begun 2003; Smits and Monden 2009; Wilmoth and Horiuchi 1999; Shkolnikov et al. 2011; Vaupel, Zhang and Raalte 2011), England and Wales (Shkolnikov et al. 2011; Vaupel, Zhang and Raalte 2011), Sweden (Wilmoth and Horiuchi 1999; Vaupel, Zhang and Raalte 2011), and Japan (Wilmoth and Horiuchi 1999; Vaupel, Zhang and Raalte 2011). On the contrary, Assam females having the lowest life expectancy in 2011 had the highest life disparity and the lowest threshold age. However, there are a few exceptions. In Andhra Pradesh, males have a relatively high life expectancy at birth compared to the central states. But the life disparity is second highest, and the threshold age is second lowest among the selected states. Compared to other selected states, males in Andhra Pradesh have higher than expected midlife mortality and lower than expected old age mortality, both of which contribute to high life disparity. This kind of inconsistency has been found in other studies as well. For example, for the USA, the life disparity is substantially higher than might be predicted from their high levels of life expectancy (Edwards and Tuljapurkar 2005; Shkolnikov, Andrew and Begun 2003; Smits and Monden 2009).

Results from the study provide valuable insight into changes in life disparity in India over the last three decades. The findings suggest that early life disparity has reduced considerably in India and the 15 major states. There is also a definite interrelationship between the decline in early life disparity and increase in life expectancy at birth in India (**Appendix**). The male-female comparison in the measurement of life disparity suggests that females have experienced a higher decline in loss of life years due to premature mortality than males. For example, in males, the life expectancy increased by 8 years, the life disparity decreased by 3.6 years, and the threshold age increased by 5.5 years between 1981 and 2011. In comparison, in females, the life expectancy increased by 12 years, the life disparity decreased by 5.2 years, and the threshold age increased by 7.2 years. These not only hint towards greater improvement in life expectancy for females, but also towards the fact that the decline in age-at-death inequalities was stronger in females compared with males. The trend in Gini coefficient for males and females also suggests similar picture. This is of particular importance because both the males and females had the same life expectancy at birth (56 years) in 1981. These findings are consistent with the findings of previous studies that report that females face more certainty in their lifetimes (Edwards and Tuljapurkar 2005; Singh and Ladusingh 2016; Vaupel, Zhang and Raalte 2011). One of the key reasons for lower life disparity in females compared to males is the higher decline in infant and child mortality in females in the last three decades. The mortality transition in females was also faster compared to the males during the 1970s (Rajaratnam et al. 2010).

An interesting pattern emerges when we look at the trends in life expectancy, life disparity, threshold age, and Gini coefficient for urban and rural areas. In urban areas, the life expectancy increased by 6 years, the life disparity decreased by 3.4 years, the threshold age increased by 5.4 years, and the Gini coefficient declined by a little more than 5 points. On the contrary, in rural areas, the life expectancy increased by 10 years, the life disparity decreased by 4.2 years, the threshold age increased by 6.5 years, and the Gini coefficient declined by a little more than 8 points. With significant improvement in rural areas, the life disparity in rural and urban areas have come very close in 2011 (12.9 versus 11.5). Trends in life expectancy by urban-rural residence also suggest convergence. Notably, increase in threshold age provides a window for decreasing life disparity. With the increase in threshold age, life expectancy has increased and life disparity has decreased. Interestingly, there is a convergence in threshold age and life expectancy at birth over the last three decades for males, females, and rural residents. In contrast, the gap between life expectancy and threshold age in urban areas has widened during the study period. The widening of the gap indicates towards the expansion of mortality and hence small reduction in life disparity in urban areas. These results are in line with the theory which suggests that when threshold age is lesser than life expectancy at birth even if people die prematurely they contribute to expand the mortality inequality whereas if the threshold age is closer or greater than life expectancy then only those dying after the expected length of life contribute to expansion.

Differential mortality patterns in different socio-economic groups of the states can also explain the differentials in the life span variations at the state level. Generally, lower socio-economic classes have lower life expectancy and experience higher lifespan variation at all levels of life expectancy. On the contrary, higher socio-economic classes experience lower life span variations. This can be easily observed by simply comparing the inequality measures across the different states of India. The states from the central and eastern parts of India – that are socio-economically poorer and face plenty of vulnerabilities like high incidence of communicable diseases, high fatality, etc. – have lower life expectancy and higher life span variations compared to the south Indian and selected north Indian states (Chaurasiya 2010; Rajaratnam et al. 2010). The life disparity for Kerala (a south Indian state) females and males is similar to what is observed for developed countries like Sweden, Norway, Japan, etc. (Vaupel, Zhang & Raalte 2011). The states like Assam, Uttar Pradesh, and Madhya Pradesh have a life disparity that is similar to Russia and Ukraine. Interestingly, the life disparity for Indian males and females is very close to life disparity for Chinese males and females (Vaupel, Zhang & Raalte 2011).

The limitations of our study must be noted. In the absence of complete life tables for India and the 15 major states, we estimated modelled complete life tables using Heligman Pollard eight-parameter model, Brass logit model, Kostaki relational model, and Bessel spline model. Based on a number of investigations we decided to go ahead with the Bessel spline model. Although Bessel spline performed better than the other three models, errors in the estimated age schedules cannot be ruled out. To check the robustness of our estimates, we calculated Gini coefficients after estimating modelled complete life tables using the Heligman Pollard eight-parameter model. The estimated Gini coefficients were slightly higher than those presented in our paper. Interestingly, the trends and differentials remained unchanged. The estimated Gini coefficients based on Heligman Pollard eight-parameter model lied between estimates presented in this paper and those presented in Singh et al. (2017). It is less problematic than thought if our estimates of the lifespan dispersion are taken as a lower bound on the actual lifespan dispersion in India and the selected states. We also examined how well the Bessel spline smoothing worked for ages 70-74, 75-79, and 80-84 for the recent life tables. The observed and the estimated probability of deaths for ages 70-74, 75-79, and 80-84 were close for males. For females, there was no difference between the observed and the estimated probabilities. Second, we could only do a trend analysis for the last three decades due to the non-availability of quality Indian life tables and statistics on death before that. The Indian SRS started giving life tables and statistics on mortality during the 1970s. However, the quality of data during the initial period is questionable. Given this, our study is the by far the only study that systematically examines the trends in inequality in length of life in India and the 15 major states. Although we realize that the socio-economic inequality in life span in India is likely to be much larger than male-female differences or rural-urban differences, we could not carry out the inequality analysis by socio-economic groups due to the non-availability of life tables and mortality statistics by various socio-economic groups. The SRS provides mortality statistics only by male-female and urban-rural residence. The vital registration system in India is also largely incomplete. Fourth, we could not decompose the difference in life disparity by causes of deaths in India and states. The data on causes of deaths are limited in India. The Global Burden of Disease (GBD) study provides data on broad causes of deaths only at the national level. The decompositions based on broad causes of deaths may not yield much insight.

This is perhaps the first study from India or other emerging countries which compares the estimated age schedules of mortality obtained from various suggested smoothing methods. This study is also the first to compare the lifespan variations obtained by estimating modelled age schedules compared with none at all. We selected Gini coefficient, life disparity, and threshold age to examine the lifespan variations in India and selected sub-populations. These are widely used statistics to measure lifespan variations. Our interpretations based on Gini coefficient and life disparity are largely similar. Vaupel, Zhang and Raalte (2011), in their study on the international comparison of life table data, also show a high correlation of life disparity with other measures of life span variations. In their study, the correlation of life disparity with other measures never lied below 0.966 for females and 0.940 for males. The similarity of results based on Gini coefficient and the life disparity indicates towards the robustness of our findings.

**Conclusion**

Cross-country analyses have shown that countries achieving higher levels of life expectancy have done so by reducing premature mortality. Reducing premature mortality can help India in achieving higher levels of life expectancy and lower levels of life disparity. India has every potential to reduce its life disparity to a level that is close to developed world. In fact, the life disparity for Kerala males and females is similar to those observed in some of the most developed countries. If Kerala can reduce premature mortality to such a level, there is no reason why other states cannot. Reducing premature mortality helps people plan better as the uncertainty in life reduces. Such a situation is very beneficial for the socio-economic development of a population. Finally, there is a need for regular and rigorous monitoring of life span variations in India. Regular and rigorous monitoring of life span variations helps the national and state governments to evaluate the performance of various social and health protective policies launched from time to time.

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**Table 1: Values of the sum of squares of absolute deviations between the resulting and empirical $q_x$ values , multiplied by 10^3**

| | | Expanding Methodology | | | |
|---|---|---|---|---|---|
| **Life Table** | **Helligman Pollard 8 parameter model** | **Brass Logit** | **Bessel Spline** | **Kostaki Model** | **Flexi Spline** |
| India, 2010-14 | 0.0605 | 0.37241 | 0.000140 | 0.02987 | 0.000142 |
| India Male, 2010-14 | 0.0527 | 0.5680 | 0.000129 | 0.04531 | 0.00032 |
| India Female, 2010-14 | 0.0759 | 0.32755 | 0.000193 | 0.00851 | 0.00026 |
| India Rural, 2010-14 | 0.0935 | 0.3855 | 0.000187 | 0.04990 | 0.00025 |
| India Urban, 2010-14 | 0.02161 | 0.1972 | 0.000242 | 0.12535 | 0.00024 |

**Table 2: Values of the sum of squares of relative deviations between the resulting and empirical qx values 3**

| | | Expanding Methodology | | | |
|---|---|---|---|---|---|
| **Life Table** | **Heligman Pollard 8 parameter model** | **Brass Logit** | **Bessel Spline** | **Kostaki Model** | **Flexi Spline** |
| India, 2010-14 | 0.0164 | 0.5896 | 0.741 | 0.0495 | 0.7440 |
| India Male, 2010-14 | 0.02 | 2.2401 | 0.713 | 0.0801 | 0.264 |
| India Female, 2010-14 | 0.0143 | 0.79490 | 0.282 | 0.0043 | 0.318 |
| India Rural, 2010-14 | 0.0156 | 0.1199 | 0.192 | 0.1102 | 0.2036 |
| India Urban, 2010-14 | 0.09605 | 0.3125 | 0.734 | 0.1555 | 0.6506 |

**Figure 1: Empirical qx – values (points) and estimations by (1) the Heligman Pollard eight-parameter model, (2) Brass logit model, (3) Kostaki relational model, and (4) Bessel spline, for Indian females, 2010-2014**

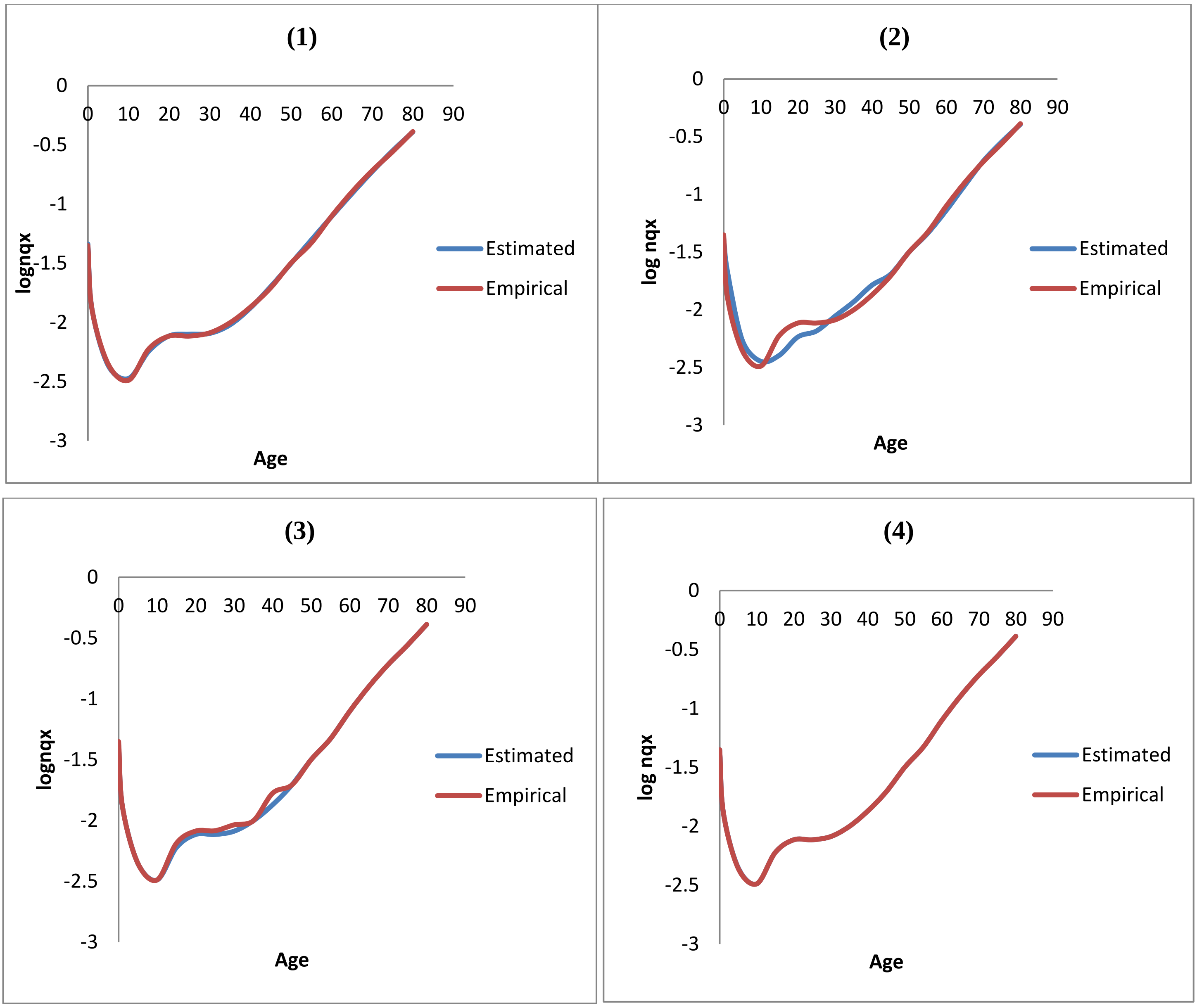


**Figure 2: Trends in Gini coefficient for males and females, India and major states, 1981, 1991, 2001, 2011**

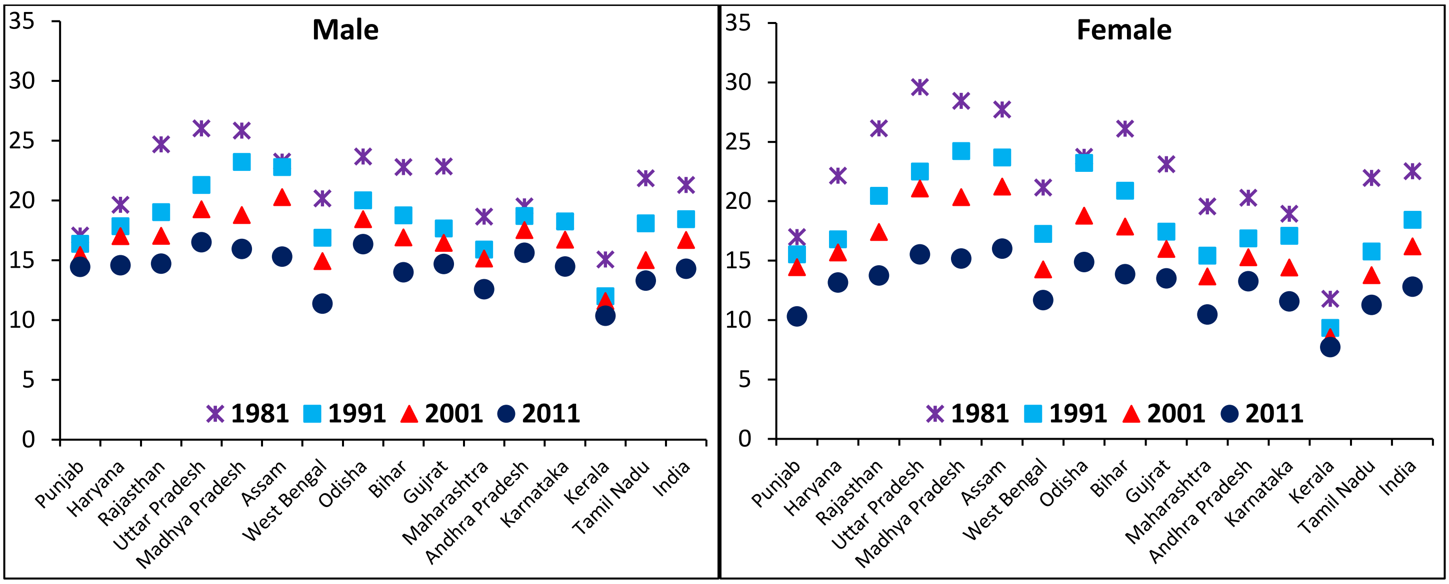



**Figure 3: Trends in Gini coefficient for urban and rural, India and major states, 1981, 1991, 2001, 2011**

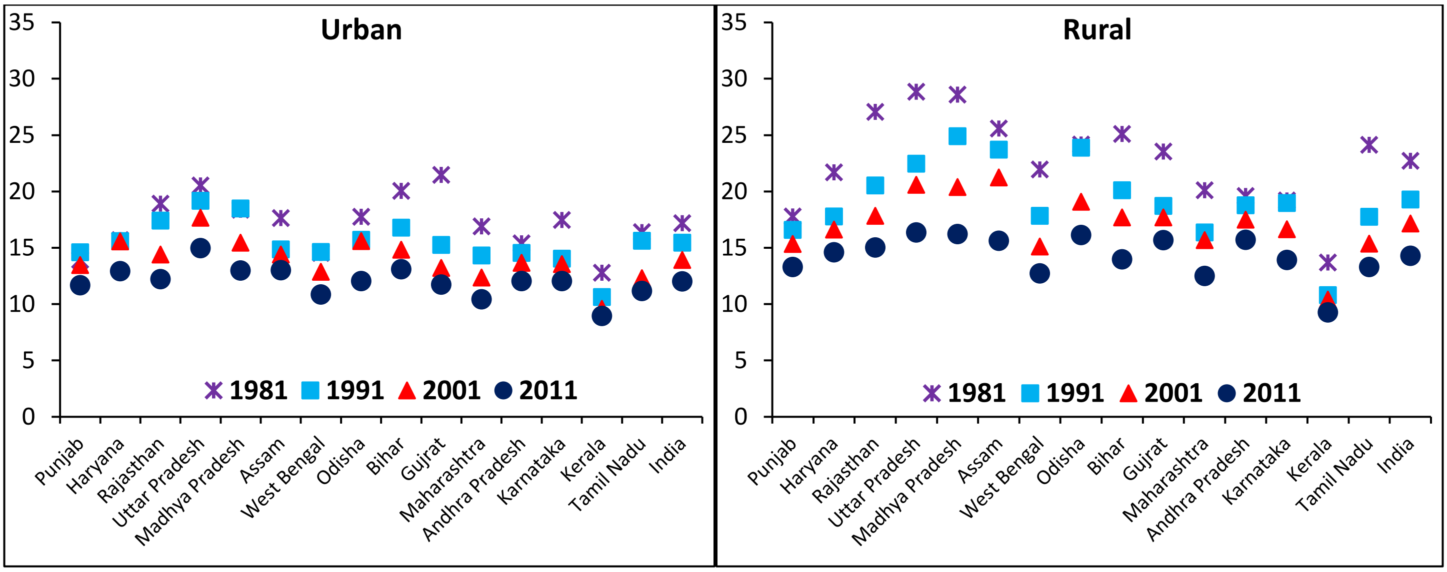


**Table 3: Trends in life expectancy (LE) at birth, life disparity (e+) and threshold age (a+) , males, India & major states, 1981, 1991, 2001, and 2011**

| | LE | | | | e+ | | | | a+ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1981 | 1991 | 2001 | 2011 | 1981 | 1991 | 2001 | 2011 | 1981 | 1991 | 2001 | 2011 |
| *North* | | | | | | | | | | | | |
| **Punjab** | 60.9 | 61.7 | 64.5 | 65.5 | 13.5 | 13.6 | 13.9 | 13.4 | 65.6 | 63.8 | 63.9 | 64.8 |
| **Haryana** | 58.9 | 61.9 | 62.4 | 63.9 | 15.9 | 14.9 | 14.7 | 13.2 | 58.1 | 63.5 | 62.4 | 62.1 |
| **Rajasthan** | 53.1 | 58.4 | 62.1 | 64.0 | 18.0 | 14.9 | 14.4 | 13.0 | 55.8 | 60.9 | 63.3 | 63.5 |
| *Central* | | | | | | | | | | | | |
| **Uttar Pradesh** | 53.5 | 58.1 | 60.5 | 61.9 | 19.3 | 16.9 | 16.3 | 14.7 | 55.8 | 59.4 | 59.5 | 59.6 |
| **Madhya Pradesh** | 52.1 | 54.9 | 59.5 | 61.7 | 18.4 | 17.3 | 15.4 | 13.3 | 54.4 | 57.4 | 59.3 | 63.2 |
| *North East* | | | | | | | | | | | | |
| **Assam** | 53.8 | 55.4 | 57.4 | 61.3 | 17.5 | 17.9 | 16.2 | 12.7 | 53.6 | 54.7 | 56.5 | 62.4 |
| *East* | | | | | | | | | | | | |
| **West Bengal** | 56.5 | 60.9 | 63.9 | 66.3 | 15.5 | 14.1 | 13.5 | 10.5 | 57.2 | 61.4 | 62.8 | 65.2 |
| **Odisha** | 55.3 | 55.1 | 58.9 | 63.2 | 18.2 | 17.1 | 14.9 | 14.3 | 55.4 | 57.6 | 60.9 | 63.6 |
| **Bihar** | 55.7 | 59.8 | 63.1 | 65.3 | 17.2 | 15.4 | 14.8 | 12.7 | 58.4 | 60.8 | 62.3 | 65.7 |
| *West* | | | | | | | | | | | | |
| **Gujrat** | 55.3 | 59.7 | 62.5 | 64.2 | 17.2 | 14.6 | 14.2 | 13.1 | 56.3 | 59.7 | 62.6 | 64.7 |
| **Maharashtra** | 59.4 | 61.4 | 63.4 | 66.2 | 15.1 | 13.5 | 13.5 | 11.8 | 60.9 | 61.7 | 62.5 | 64.2 |
| *South* | | | | | | | | | | | | |
| **Andhra Pradesh** | 58.5 | 58.2 | 60.8 | 63.3 | 15.5 | 15.1 | 15.1 | 14.3 | 60.1 | 57.6 | 58.8 | 60.6 |
| **Karnataka** | 60.1 | 59.7 | 61.9 | 63.5 | 15.1 | 14.9 | 14.5 | 12.9 | 60.8 | 60.8 | 61.9 | 63.9 |
| **Kerala** | 62.8 | 65.4 | 66.2 | 67.6 | 13.1 | 10.9 | 10.9 | 9.9 | 62.2 | 65.5 | 64.8 | 66.7 |
| **Tamil Nadu** | 56.5 | 59.4 | 63.3 | 65.6 | 17.1 | 14.8 | 13.3 | 12.5 | 56.4 | 59.7 | 62.4 | 63.3 |
| **India** | **55.9** | **59.1** | **61.9** | **64.0** | **16.5** | **15.1** | **14.4** | **12.8** | **58.1** | **60.3** | **61.6** | **63.6** |

**Table 4: Trends in life expectancy (LE) at birth, life disparity (e+) and threshold age (a+) , females, India & major states, 1981, 1991, 2001, and 2011**

| | LE | | | | e+ | | | | a+ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1981 | 1991 | 2001 | 2011 | 1981 | 1991 | 2001 | 2011 | 1981 | 1991 | 2001 | 2011 |
| *North* | | | | | | | | | | | | |
| **Punjab** | 62.9 | 66.2 | 67.8 | 70.1 | 13.9 | 14.1 | 13.5 | 10.1 | 67.7 | 66.7 | 67.6 | 69.8 |
| **Haryana** | 57.6 | 63.5 | 66.2 | 69.0 | 16.7 | 14.4 | 14.1 | 12.9 | 63.5 | 64.2 | 67.7 | 66.3 |
| **Rajasthan** | 54.4 | 60.2 | 65.7 | 67.9 | 19.3 | 16.4 | 15.7 | 12.7 | 57.2 | 63.3 | 66.6 | 68.9 |
| *Central* | | | | | | | | | | | | |
| **Uttar Pradesh** | 52.5 | 58.4 | 60.6 | 65.1 | 21.5 | 17.8 | 17.5 | 13.8 | 57.6 | 61.8 | 61.2 | 65.2 |
| **Madhya Pradesh** | 51.0 | 55.6 | 60.5 | 64.7 | 21.2 | 17.9 | 16.6 | 13.2 | 57.1 | 60.3 | 63.9 | 65.5 |
| *North East* | | | | | | | | | | | | |
| **Assam** | 53.5 | 54.7 | 59.8 | 64.7 | 22.1 | 17.7 | 18.1 | 14.9 | 48.6 | 56.6 | 57.8 | 62.9 |
| *East* | | | | | | | | | | | | |
| **West Bengal** | 57.2 | 61.7 | 66.0 | 68.9 | 16.2 | 14.4 | 13.3 | 11.5 | 60.7 | 62.4 | 64.6 | 66.0 |
| **Odisha** | 54.9 | 56.2 | 61.2 | 64.9 | 17.5 | 17.8 | 15.7 | 13.1 | 55.1 | 58.6 | 62.1 | 65.2 |
| **Bihar** | 52.8 | 59.3 | 63.9 | 66.2 | 19.0 | 16.8 | 15.8 | 12.7 | 54.7 | 61.6 | 63.5 | 65.5 |
| *West* | | | | | | | | | | | | |
| **Gujrat** | 57.3 | 62.9 | 65.5 | 68.8 | 17.9 | 15.0 | 14.4 | 13.1 | 60.3 | 63.5 | 65.5 | 67.7 |
| **Maharashtra** | 60.5 | 63.5 | 65.7 | 70.2 | 16.2 | 13.2 | 12.3 | 10.6 | 61.4 | 64.2 | 65.0 | 68.8 |
| *South* | | | | | | | | | | | | |
| **Andhra Pradesh** | 58.7 | 61.2 | 65.4 | 67.9 | 16.0 | 13.9 | 13.8 | 12.6 | 61.7 | 62.2 | 65.9 | 66.1 |
| **Karnataka** | 60.5 | 62.2 | 66.5 | 68.9 | 15.5 | 14.3 | 13.2 | 11.3 | 62.5 | 64.6 | 66.2 | 67.5 |
| **Kerala** | 67.7 | 69.8 | 70.9 | 72.6 | 10.9 | 9.3 | 8.8 | 8.3 | 67.6 | 68.8 | 69.9 | 70.8 |
| **Tamil Nadu** | 56.8 | 62.5 | 66.3 | 69.3 | 16.9 | 13.3 | 12.7 | 11.1 | 59.5 | 65.0 | 65.5 | 67.3 |
| **India** | **56.0** | **60.4** | **64.4** | **67.5** | **17.4** | **15.1** | **14.4** | **12.1** | **59.7** | **62.9** | **64.9** | **66.9** |

**Table 5: Trends in life expectancy (LE) at birth, life disparity (e+) and threshold age (a+) , urban, India & major states, 1981, 1991, 2001, and 2011**

| | LE | | | | e+ | | | | a+ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1981** | **1991** | **2001** | **2011** | **1981** | **1991** | **2001** | **2011** | **1981** | **1991** | **2001** | **2011** |
| ***North*** | | | | | | | | | | | | |
| **Punjab** | 65.1 | 67.5 | 66.2 | 69.3 | 12.2 | 14.0 | 12.5 | 11.6 | 66.6 | 65.7 | 65.4 | 67.6 |
| **Haryana** | 62.9 | 63.9 | 63.6 | 68.0 | 13.3 | 13.8 | 13.9 | 12.5 | 64.8 | 64.0 | 62.9 | 66.5 |
| **Rajasthan** | 64.0 | 64.1 | 66.4 | 67.5 | 18.0 | 16.3 | 13.6 | 11.5 | 58.6 | 60.8 | 64.7 | 66.8 |
| ***Central*** | | | | | | | | | | | | |
| **Uttar Pradesh** | 58.8 | 61.4 | 62.3 | 66.1 | 16.2 | 16.4 | 15.2 | 13.9 | 61.7 | 61.0 | 62.5 | 64.8 |
| **Madhya Pradesh** | 59.2 | 59.6 | 63.2 | 66.3 | 14.7 | 14.9 | 13.7 | 11.8 | 60.8 | 61.6 | 62.7 | 66.7 |
| ***North East*** | | | | | | | | | | | | |
| **Assam** | 60.3 | 62.9 | 64.1 | 67.4 | 14.6 | 13.3 | 13.3 | 12.5 | 59.6 | 60.8 | 61.5 | 65.7 |
| ***East*** | | | | | | | | | | | | |
| **West Bengal** | 63.6 | 63.8 | 67.5 | 68.5 | 12.6 | 12.9 | 12.6 | 10.5 | 64.6 | 63.8 | 64.9 | 67.9 |
| **Odisha** | 61.7 | 63.9 | 64.6 | 66.7 | 15.3 | 14.5 | 14.3 | 11.2 | 61.0 | 60.9 | 63.0 | 66.2 |
| **Bihar** | 61.8 | 64.6 | 64.9 | 67.7 | 18.6 | 15.2 | 13.0 | 12.4 | 55.9 | 63.7 | 66.6 | 66.8 |
| ***West*** | | | | | | | | | | | | |
| **Gujrat** | 57.3 | 61.6 | 67.0 | 68.0 | 16.9 | 12.9 | 12.6 | 11.2 | 57.9 | 61.8 | 65.5 | 67.6 |
| **Maharashtra** | 63.0 | 64.4 | 66.2 | 69.4 | 15.1 | 12.7 | 11.3 | 10.4 | 61.0 | 64.8 | 66.5 | 67.8 |
| ***South*** | | | | | | | | | | | | |
| **Andhra Pradesh** | 64.4 | 63.1 | 66.4 | 68.4 | 14.1 | 12.9 | 13.0 | 11.8 | 62.7 | 62.5 | 64.5 | 66.8 |
| **Karnataka** | 64.2 | 63.2 | 66.1 | 68.3 | 16.2 | 12.0 | 12.7 | 11.7 | 61.7 | 64.5 | 64.8 | 66.8 |
| **Kerala** | 66.6 | 68.8 | 69.3 | 70.5 | 12.3 | 10.6 | 9.6 | 9.6 | 64.5 | 66.8 | 67.7 | 68.1 |
| **Tamil Nadu** | 62.0 | 62.4 | 67.4 | 68.4 | 14.3 | 13.6 | 11.8 | 10.8 | 61.4 | 61.8 | 65.9 | 67.7 |
| **India** | **62.0** | **63.0** | **66.1** | **68.1** | **14.9** | **13.7** | **12.9** | **11.5** | **61.5** | **62.9** | **64.6** | **66.9** |

**Table 6: Trends in life expectancy (LE) at birth, life disparity (e+) and threshold age (a+) , rural, India & major states, 1981, 1991, 2001, and 2011**

| | LE | | | | e+ | | | | a+ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1981** | **1991** | **2001** | **2011** | **1981** | **1991** | **2001** | **2011** | **1981** | **1991** | **2001** | **2011** |
| ***North*** | | | | | | | | | | | | |
| **Punjab** | 61.1 | 62.6 | 66.0 | 66.7 | 13.9 | 13.9 | 14.0 | 12.2 | 65.5 | 64.8 | 65.9 | 66.9 |
| **Haryana** | 57.4 | 62.3 | 64.3 | 65.4 | 16.8 | 14.9 | 14.5 | 13.4 | 60.3 | 64.4 | 65.8 | 64.3 |
| **Rajasthan** | 51.9 | 58.5 | 63.2 | 65.5 | 19.2 | 16.1 | 15.3 | 13.5 | 55.9 | 61.8 | 64.4 | 65.9 |
| ***Central*** | | | | | | | | | | | | |
| **Uttar Pradesh** | 52.2 | 57.6 | 60.2 | 62.9 | 20.9 | 17.6 | 17.2 | 14.4 | 55.6 | 60.0 | 60.8 | 62.6 |
| **Madhya Pradesh** | 50.3 | 54.3 | 59.4 | 62.3 | 19.5 | 18.3 | 16.5 | 13.6 | 55.1 | 58.3 | 61.1 | 63.9 |
| ***North East*** | | | | | | | | | | | | |
| **Assam** | 52.7 | 54.5 | 57.7 | 61.9 | 19.2 | 18.0 | 17.2 | 13.3 | 51.6 | 55.0 | 56.6 | 62.6 |
| ***East*** | | | | | | | | | | | | |
| **West Bengal** | 55.1 | 60.4 | 64.0 | 67.2 | 16.4 | 14.6 | 13.6 | 12.3 | 58.7 | 61.7 | 62.8 | 64.9 |
| **Odisha** | 54.5 | 54.8 | 59.5 | 63.6 | 17.9 | 17.8 | 15.4 | 14.1 | 57.5 | 57.7 | 61.5 | 64.6 |
| **Bihar** | 53.6 | 59.2 | 63.3 | 65.5 | 18.4 | 16.2 | 15.6 | 12.7 | 56.1 | 60.5 | 62.7 | 65.4 |
| ***West*** | | | | | | | | | | | | |
| **Gujrat** | 55.9 | 61.1 | 62.6 | 65.5 | 17.8 | 15.9 | 15.2 | 14.5 | 58.8 | 60.9 | 63.1 | 64.1 |
| **Maharashtra** | 58.6 | 61.6 | 63.6 | 67.2 | 15.9 | 13.7 | 13.9 | 11.9 | 60.9 | 62.8 | 63.1 | 65.8 |
| ***South*** | | | | | | | | | | | | |
| **Andhra Pradesh** | 56.4 | 58.8 | 62.1 | 64.4 | 16.6 | 15.7 | 15.3 | 14.2 | 55.5 | 57.9 | 61.2 | 63.3 |
| **Karnataka** | 59.1 | 60.1 | 63.3 | 65.0 | 15.4 | 15.5 | 14.6 | 12.6 | 60.2 | 61.6 | 63.7 | 64.6 |
| **Kerala** | 65.0 | 67.4 | 68.3 | 69.9 | 12.2 | 10.1 | 10.1 | 9.4 | 65.4 | 67.0 | 67.4 | 68.4 |
| **Tamil Nadu** | 54.5 | 60.2 | 63.6 | 66.7 | 17.9 | 14.4 | 13.5 | 12.8 | 56.9 | 61.9 | 66.4 | 64.5 |
| **India** | **54.8** | **58.9** | **62.3** | **64.9** | **17.2** | **15.5** | **14.8** | **12.9** | **58.3** | **61.1** | **63.1** | **64.8** |

**Figure 4: Age specific contributions to the decrease in Gini coefficient for males and females between 1981 and 2011, India and major states**

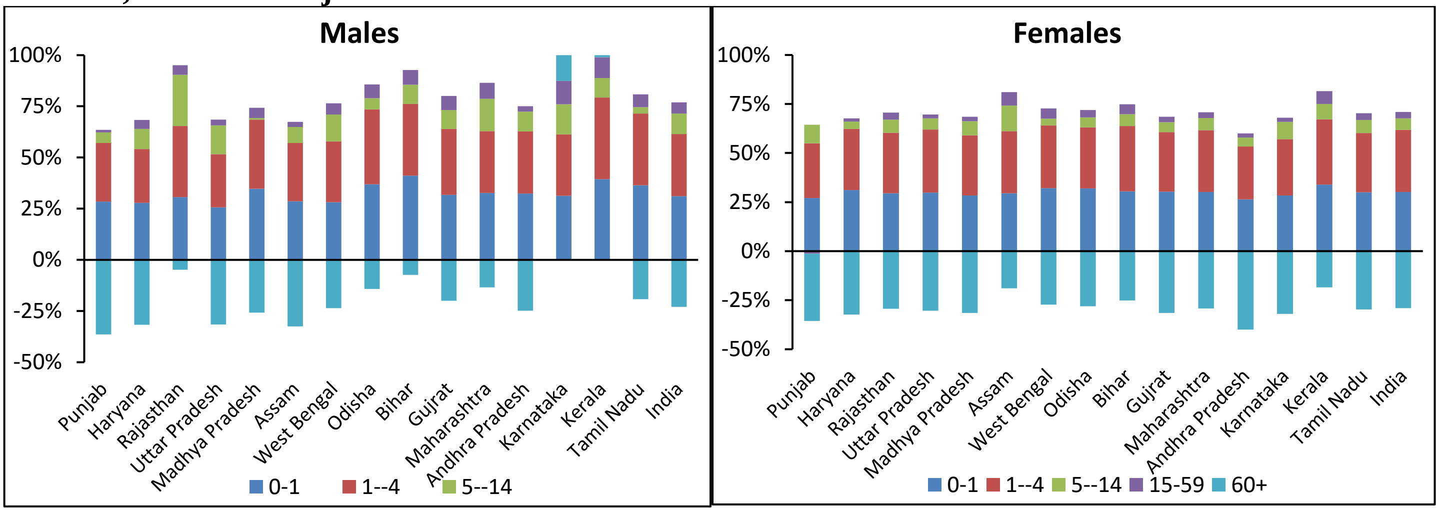
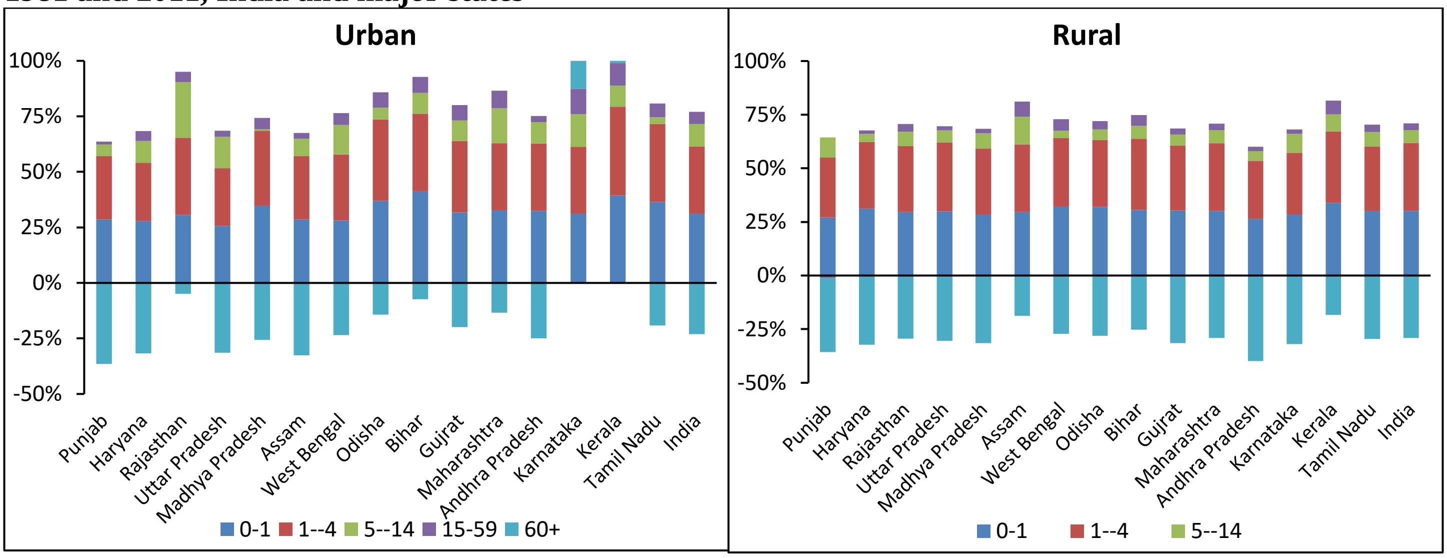



**Figure 5: Age specific contributions to the decrease in Gini coefficient for urban and rural areas between 1981 and 2011, India and major states**



# Appendix

**Figure A: Trends in life disparity and threshold age for males and females between 1981 and 2011, India major states**

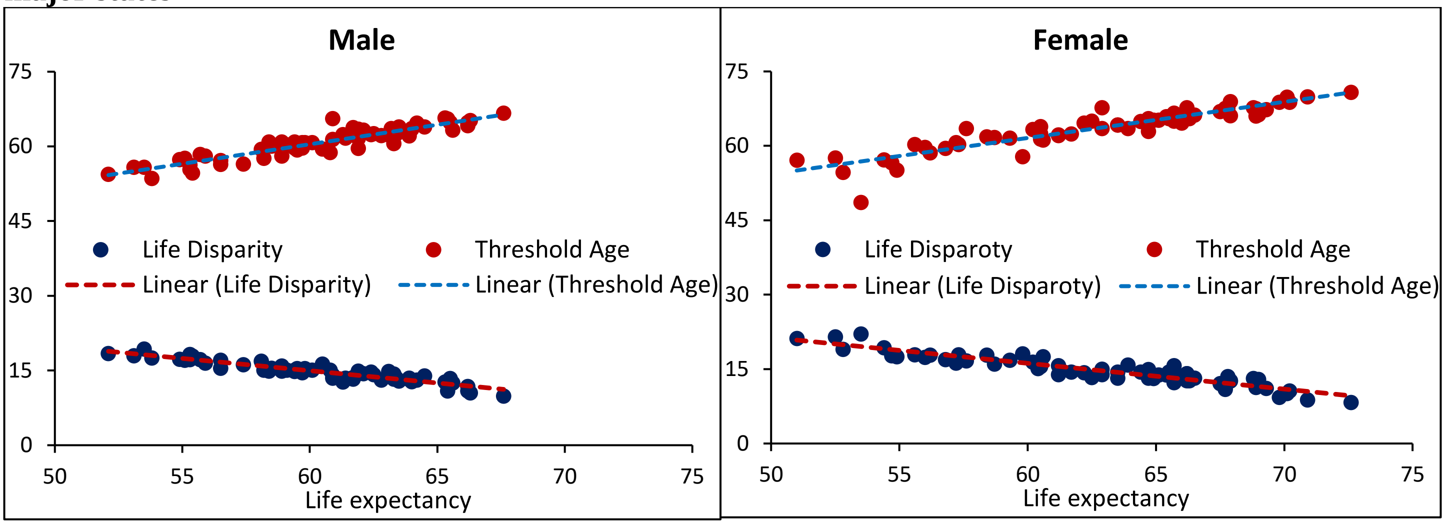



**Figure B: Trends in life disparity and threshold age for urban and rural between 1981 and 2011, India and major states**